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QUANTIFICATION OF THE PROBABLE EFFECTS OF ALTERNATIVE IN-RIVER HARVEST REGULATIONS ON RECOVERY OF SNAKE RIVER FALL CHINOOK SALMON

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QUANTIFICATION OF THE PROBABLE EFFECTS OF ALTERNATIVE IN-RIVER HARVEST REGULATIONS ON RECOVERY OF SNAKE RIVER FALL CHINOOK SALMON

FINAL REPORT
March 1996

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EXECUTIVE SUMMARY

The goal of the study reported here was to quantify the probable effects that alternative strategies for managing in-river harvest would have on recovery of Snake River fall chinook salmon. This report presents our analysis of existing data to quantify the way in which various in-river harvest strategies catch Snake River bright (SRB) fall chinook. Because there has been disagreement among experts regarding the magnitude of in-river harvest impacts on Snake River fall chinook, we compared the results from using the following three different methods to estimate in-river harvest rates.

1. Use of run reconstruction through stock accounting of escapement and landings data to estimate harvest rate of SRB chinook in Zone 6 alone.

2. Use of Coded Wire Tag (CWT) recoveries of fall chinook from Lyons Ferry Hatchery in a cohort analysis to estimate age and sex specific harvest rates for Zone 6 and for below Bonneville Dam.

3. Comparison of harvest rates estimated for SRB chinook by the above methods to those estimated by the same methods for Upriver Bright (URB) fall chinook.

In-river harvest rates estimated by all methods indicated that harvest rates were similar between ages 4, 5, and 6, but that harvest rates were substantially reduced at age 3. Because harvest rates at age 3 are lower than those at age 4-6, inclusion of age 3 fish in the calculation of average harvest rate {as is the practice of the Columbia River Compact Technical Advisory Committee (TAC)} causes the average harvest rate to be less than is actually experienced by most adult females. Fish returning at age 3 from subyearling releases were 60% to 80% males. The age and sex-structured cohort analysis demonstrated that, as a consequence of including age 3 fish in the calculation of average harvest rate, the average harvest rate is always less than that on age 4 fish, generally by 10 to 15 percentage points. Further, age 3 fish have composed a highly variable proportion of the run entering the Columbia River, so the inclusion of age 3 fish in the average harvest rate would have reduced the average by varying amounts between years.

Harvest rates estimated by the stock accountability method for age 46 SRB chinook averaged about 85% of those for URB chinook during 1986-l 992. The timing of catch of SRB and URB chinook in Zone 6 was similar, so we found no substantive evidence that harvest rates should differ between URB and SRB chinook. We concluded that the harvest rates estimated on URB chinook should be accepted as the best estimates of harvest rate on SRB chinook also, because URB chinook destined for the mid Columbia composed the vast majority of the landings in Zone 6 and the escapement over McNary Dam.

Harvest rates estimated by cohort analysis were consistently higher than those estimated by stock accountability. We examined the possible sources of bias that might cause these differences. The extremely high harvest rates estimated by cohort analysis for Priest Rapids chinook resulted from the standard assumption of no mortality above McNary Dam. We determined by iteration that a 50% mortality had to be assigned to the Priest Rapids fish above McNary Dam before the estimated harvest rates came into line with those estimated by stock accountability. We determined that interdam conversion rates were not a major source of bias, but that expansion factors used for CWT recoveries from spawners were the largest source of bias for cohort analysis of Lyons Ferry CWT's. Additionally, differential fallback rates of marked and unmarked fish at Ice Harbor Dam could have caused the high estimates of harvest rate produced by cohort analysis of CWT's.

We hypothesize that harvest-related mortalities may be responsible for previously unaccounted interdam losses. Inter-dam conversion rates of URB's between Bonneville and Lower Granite dams are inversely related to harvest level in Zone 6 (R^2= 0.66); i.e., the highest levels of unaccounted loss have occurred during the years of high in-river harvest levels. This observed empirical relationship could be caused by several factors, such as -- increased opportunity for illegal take, increased incidental fishing mortality, and delayed mortality due to net and hook injury -- during high harvest. The magnitude of the latent mortality mechanism is substantiated by the harvestcaused wounding rates of fall chinook salmon observed at Ice Harbor Dam, i.e., an average of about 31% during 1991-1993. This high level of wounding caused by fishing could result in significant levels of pre-spawning mortality -- especially in years when water temperatures in the Snake River are high.

The CRiSP.2 harvest model was used to simulate effects of alternative harvest strategies on Snake River fall chinook salmon spawning escapement. This model, developed by Jim Norris of the University of Washington, is patterned after the Pacific Salmon Commission (PSC) chinook model. A sensitivity analysis showed that the environmental variability (EV) scalar had an overriding effect on the model results. An EV scalar value of 4.8 (used by PSC in forecasts) results in rapid rebuilding of SRB's to an escapement level of 6,000 spawners under a status quo harvest management regime. However, based on the decreasing trends observed in the empirical escapement data, we determined an EV-scalar value of 2.0 was more realistic for simulations of alternative harvest scenarios.

The 45,000 fixed escapement policy for URB's at McNary Dam does not ensure adequate spawning escapement of SRB's. The 45,000 goal is not sensitive to the differential abundance of SRB's to URB's -- that ratio has varied from 0.4% to 1.6% in recent years. Simulation modeling showed that managing a mixed-stock river harvest of URB's to achieve a 45,000 run size past McNary Dam will result in extinction of SRB's. A fixed escapement goal of about 115,000 to 125,000 URB's would be needed to achieve stabilization and recovery of Snake River fall chinook salmon. An escapement goal for natural spawning Snake River fall chinook salmon (e.g., at Lower Granite Dam) would be a more direct and effective policy to conserve and recover the ESA-listed stock.

Simulation modeling indicated that selective harvest of mid-Columbia URB's (i.e., live capture and release of SRB's) could enable continued in-river harvest while allowing recovery of SRB's. However, in order to result in the stabilization and recovery of Snake River fall chinook -- the selective harvest methodology would need to be 70-100% effective in reducing harvest mortality on SRB's.

A critical uncertainty in simulation modeling -- for both the CRiSP.2 and PSC chinook models -- is the parameters of the production function. Currently, no stock-recruit data exist for naturally spawning Snake River fall chinook salmon. The only comparable data set is derived from CWT releases of subyearling Lyons Ferry fall chinook salmon. Currently the data set for the surrogate hatchery stock is not adequate to estimate a valid stock-recruitment relationship. Furthermore, the current Lyons Ferry hatchery practice of yearling releases (which have a different life history pattern) is further impeding the development of this critical research information.

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PROBABLE EFFECTS OF ALTERNATIVE IN-RIVER HARVEST REGULATIONS ON RECOVERY OF SNAKE RIVER FALL CHINOOK SALMON

INTRODUCTION

The Snake River Salmon Recovery Team (SRSRT 1993) concluded that, “modification of the harvest of Snake River salmon, and reduction of harvest rates on fall chinooks are vital to an early start for the recovery process.” However, the Recovery Team also concluded that reduction of harvest rates alone could not accomplish recovery of the population. Although the harvest of Snake River fall chinook has been the subject of much analysis and discussion by management agencies and interested parties (see Lestelle and Gilbertson 1993 for a review), there remains much uncertainty about the role that in-river harvest has played in the population decline or will play in population recovery. The Chinook Technical Team estimated that harvest rates of Lyons Ferry Hatchery fall chinook averaged 39% in the Columbia River for the 1984-86 broods (PSC 1992), while Chapman et al. (1991) estimated that in-river harvest rate had ranged from 4443% during the 1980’s. The difference in these estimates resulted from different assumed rates of interdam loss. Lestelle and Gilbertson (1993) concluded that dam conversion rates were a critical uncertainty in assessing benefits of harvest reductions.

Additional uncertainty about the impacts of harvest exists, because in-river harvest is known to be selective, but the magnitude and effects of this selection for a specific temporal portion of the run or for sizes of fish in the run have not been thoroughly analyzed. Cramer (1992) used recoveries of CWT chinook from the mid Columbia to demonstrate that harvest was highly selective for larger fish in the run. Further, Cramer et al. (1991) demonstrated temporal selection by in-river harvest had substantially altered the timing of coho runs from the Clackamas River.

The goal of the study reported here was to quantify the probable effects that alternative strategies for managing in-river harvest would have on recovery of Snake River fall chinook salmon. In order to achieve this goal, we used two analytical approaches. First, documentation of the existing data base and quantification of the impacts of various harvest strategies on Snake River fall chinook -- primarily via cohort analyses. Secondly, we use the findings from the standard harvest analysis techniques as input to the CRiSP.2 Harvest Model (Norris 1996) to simulate the future effects of various alternative scenarios for in-river harvest management on Snake River fall chinook.

IMPACTS OF IN-RIVER FISHERIES

In order to fully evaluate the impacts of in-river harvest on Snake River fall chinook, it was necessary to determine the full extent of ways in which harvest can affect population productivity over the long term. Accordingly, we analyzed not only the proportion of the population removed by harvest, but also the extent that harvest selectively removed specific segments of the population. The results of these analyses were then used to deduce how the quantity and quality (in terms of specific characteristics) of fish removed affect the production of progeny in future generations. Discussion of these topics is divided into sections on harvest rate and harvest selectivity.

HARVEST RATE

There has been concern among biologists that various assumptions required in order to estimate harvest rate may introduce bias into the estimates. The most consequential of these assumptions are those for the treatment of interdam loss, which has been identified as a critical uncertainty. Therefore, we estimated harvest rate on Snake River fall chinook (referred to as Snake River Brights or SRB's) by several different methods, and analyzed the differences in the results of these methods to identify the probable sources of bias or error associated with each method.

Alternative Estimation Methods

We pursued three approaches to estimating harvest impacts on Snake River fall chinook:

1. Use of run reconstruction through stock accounting of escapement and landings data to estimate harvest rate of SRB chinook in Zone 6 alone.
2. Use of CWT recoveries of fall chinook from Lyons Ferry Hatchery in a cohort analysis to estimate age and sex specific harvest rates for Zone 6 and for below Bonneville Dam.
3. Comparison of harvest rates estimated for SRB chinook by the above methods to those estimated by the same methods for Upriver Bright (URB) fall chinook.

The methods and results for each approach are described separately below.

Description of Methods

Method 1: Stock Accounting of Zone 6 Landings

For purposes of harvest management, fisheries agencies consider fall chinook in the Columbia River to be composed of five major components: Lower River Hatchery (LRH), Lower River Wild (LRW), Bonneville Pool Hatchery (BPH), Upriver Bright (URB), and Mid-Columbia Bright (MCB) (CRTS 1993). All spawning areas for the LRH and LRW components are below Bonneville Dam. The BPH component, which crosses Bonneville Dam, is produced at Spring Creek National Fish Hatchery, and is distinguished in the counts crossing Bonneville Dam by its dark skin color. The MCB component is hatchery fish of URB lineage that are produced at the following hatcheries below McNary Dam: Bonneville, Little White Salmon, Klickitat, and Umatilla. The URB component includes the wild Deschutes River fish and all fish spawning above McNary Dam. The Snake River Brights (SRB) are managed as a subset of the URB component.

Data that account for each stock component of the fall chinook run are compiled each year by the Washington Department of Fish and Wildlife and Oregon Department of Fish and Wildlife and are reported by Technical Advisory Committee (TAC) of the Columbia River Fisheries Management Plan (TAC 1984-1992). The procedure for dividing the run into its component involves reconstructing the run, beginning in the spawning areas, and working back downstream through the fisheries to the dam counts. The run reconstruction requires an accounting of the age composition of fish at each recovery site so that CWT recoveries can be used to estimate the number of each stock captured in the fisheries (CWT codes and mark rates are brood specific). The procedure for run reconstruction works like this:

1. Spawning escapement into each hatchery is enumerated, age sampled, and mark sampled. All CWT's are decoded and the number of each stock represented is estimated by expanding according to the fraction of fish marked among adult returns to the terminal area, or by the fraction of juveniles marked.

2. Natural spawning escapement is surveyed in most tributary and mainstem areas where spawning is common. Carcasses are sampled for age and marks. All CWT's are decoded and the number of each stock represented is estimated by expanding according to the fraction of fish marked among adult returns to the terminal area, or by the fraction of juveniles marked. The spawner escapement in each tributary is estimated, usually by mark-recapture. For the upper Columbia, the terminal accounting point is Priest Rapids Dam, where a portion of the run is mark-sampled when trapped for brood stock at Priest Rapids Hatchery.

3. For the Snake River, the terminal accounting point is Ice Harbor Dam. The proportion of the run that is adipose fin clipped (Ad marked) is counted at Ice Harbor Dam. During 19851989, the age and stock composition of the run was assumed to be the same as the brood stock at Lyons Ferry Hatchery, some of which were trapped at Ice Harbor Dam and some of which swam in to the hatchery. Since 1990, the fish trapped at Ice Harbor Dam for brood stock have been held separately from those swimming in to the hatchery, so the age and stock compositions have been calculated separately.

4. The number of fish caught in each major fishery is estimated by a statistical sampling program. Landed fish are sampled for age, length and marks. All CWT's are decoded and the number of each stock represented is estimated by expanding according to the fraction of fish marked among adult returns to the terminal area, or by the fraction of juveniles marked.

5. The number of fish at each age from each stock are assembled from the above components, until the run is reconstructed at Bonneville Dam. All fish in the count at McNary Dam not accounted for at counting and survey areas above McNary Dam are assigned to the natural spawning group in the mid Columbia River. The total number of bright fall chinook accounted for by this procedure is always less than the count of bright fall chinook at Bonneville Dam, so all age and stock components are expanded for the unaccounted proportion.

6. The number of fish at each age and from each stock escaping to tributaries below Bonneville Dam and caught in the Columbia River below Bonneville are added in to the run to estimate run size at the river mouth by age and stock.

Thus, the annual stock accounting completed by the WDFW Columbia River Fisheries Lab for TAC provides data that can be used to calculate an estimate of age-specific harvest rates of each of the main stock groupings in Columbia River fisheries. Harvest rates reported by TAC in the 1993 Biological Assessment of fall season fishery impacts on Snake River fall chinook were derived from this process and were reported as a single in-river harvest rate for "adult" chinook (Table 1). Because the run was reconstructed by age groups, not size groups, this harvest rate on "adults" was calculated as the weighted average harvest rate on age 3 through 6 fish (personal communication, R. Roller, WDFW, Battleground).

The stock accounting for major in-river fisheries was least complex in Zone 6 (Bonneville Dam to McNary Dam), and therefore, was likely most accurate in Zone 6. Because of the few stocks of fall chinook involved in the Zone 6 fishery, coupled with the high harvest rate within Zone 6, the Zone 6 fishery provides our best opportunity to draw meaningful comparisons between alternative estimates of harvest rates on **LFH** fall chinook.

The annual harvest rate of SRB chinook in Zone 6 can be estimated by:

*Equation 1. Calculation of Zone 6 **harvest** rate.*
Zone 6 harvest rate = No. **SRB's** in Zone 6 catch **/** No. **SRB's** passing Bonneville

The same formula applies to the stock accounting of **URB's**. The data developed through this process for Bonneville escapement, along with the estimated harvest rates in Zone 6 for SRB chinook are presented in Table 2. The term SRB includes both hatchery and wild Snake River fish.

Table 1. Harvest rates (HR) for Snake River and upriver bright fall chinook below the confluence of the Snake River, 1986-94 -- expressed in adult equivalents at river entry (U.S. v. Oregon TAC 1995).

YEAR	Harvest Rate		SRB/URB HR Ratio
	URB	SRB	
1986	56.86%	46.85%	82.39%
1987	57.17%	56.00%	97.96%
1988	63.84%	52.36%	82.02%
1989	57.30%	42.91%	74.88%
1990	53.25%	44.96%	84.43%
1991	40.44%	37.43%	92.57%
1992	26.32%	16.57%	62.95%
1993	27.77%	25.38%	91.40%
1994	18.18%	15.51%	85.30%
1986-90 Avg.	57.68%	48.61%	84.34%
1986-94 Avg.	44.57%	37.55%	84.26%
1991-94 Avg.	28.18%	23.72%	83.06%

Table 2. Fate of SRB chinook at each age that were counted at Bonneville Dam, 1986-1992, as estimated by run reconstruction from stock accounting. (data source: R. Roller, WDFW).

Run	Bonneville SRB Count				
Year	Age 2	Age 3	Age 4	Age 5	Age 6
1986	3608	3513	111	202	5
1987	2269	1433	10715	0	0
1988	2274	920	2331	2353	0
1989	1829	1436	2277	431	84
1990	2731	837	2665	1058	33
1991	668	1457	2438	1551	97
1992	963	1524	2554	908	76
Run	**Bonneville SRB Account**				
Year	**Age 2**	**Age 3**	**Age 4**	**Age 5**	**Age 6**
1986	2690	3480	111	194	5
1987	1572	1314	9874	0	0
1988	1847	882	2234	2246	0
1989	1157	1317	2075	392	76
1990	1807	740	2335	924	29
1991	473	1205	1937	1254	77
1992	711	1316	2197	774	65
Run	**Zone 6 Catch**				
Year	**Age 2**	**Age 3**	**Age 4**	**Age 5**	**Age 6**
1986	40	631	0	145	5
1987	5	368	4555	0	0
1988	73	133	957	1096	0
1989	0	215	937	207	49
1990	5	121	1156	445	21
1991	35	125	567	437	17
1992	0	80	252	203	8
Run	**Zone 6 Harvest Rate**				
Year	**Age 2**	**Age 3**	**Age 4**	**Age 5**	**Age 6**
1986	1.11%	17.96%	0.00%	71.78%	100.00%
1987	0.22%	25.68%	42.51%	0.00%	0.00%
1988	3.21%	14.46%	41.06%	46.58%	0.00%
1989	0.00%	14.97%	41.15%	48.03%	58.33%
1990	0.18%	14.46%	43.38%	42.06%	63.64%
1991	5.24%	8.58%	23.26%	28.18%	17.53%
1992	0.00%	5.25%	9.87%	22.36%	10.53%

Method 2: Cohort Analysis of CWT Recoveries

Historical harvest records that can be specifically identified as Snake River fall chinook data are limited to CVVT recoveries of fall chinook from Lyons Ferry Hatchery. The first juvenile fall chinook with CW's to be released from Lyons Ferry Hatchery as subyearlings were from the 1984 brood (Table 3), and compilation of recovery data for CW's is now complete through the 1986 brood. For the purposes of estimating harvest impacts on naturally produced fall chinook from the Snake River, we used only those groups that had been released as subyearlings, because wild Snake River fall chinook generally emigrate as subyearlings. CWT marked groups from Lyons Ferry Hatchery have been released as both subyearlings and yearlings, and distinctly marked groups of both types have been released on station or transported to below Ice Harbor Dam. Recoveries of CW's from these groups indicate that age at maturity of fall chinook released as yearlings tends to be older than that for fish released as subyearlings (Bugert et al. 1992). Because of the potential effects of release practices on age-at-maturity and contribution to in-river harvest, fisheries agencies have used only the CWT recoveries from fish released on station as subyearlings to represent naturally produced fish (TAC 1993).

Table 3. Groups of adipose-M/T marked fall chinook released from Lyons Ferry Hatchery on the Snake River, 1985-l 988.

TAG CODE	BROOD YEAR	RELEASE TYPE	AGE AT RELEASE	NUMBER TAGGED	ADIPOSE ONLY	NOT MARKED	TOTAL RELEASE
63/21/52	1983	On-Station	Yearling	250,831	1,769		252,600
63/32/18		On-Station	Yearling	83,611	589		84,200
63/32/26	1984	On-Station	Sub-Yearlings	78,417	236	101,400	180,053
63/32/27		On-Station	Sub-Yearlings	78,064	235	100,900	179,199
63/32/28		On-Station	Sub-Yearlings	78,504	236	101,400	180,140
63/28/41		On-Station	Yearling	258,355	1,821		260,176

Table 3. (continued).

TAG CODE	BROOD YEAR	RELEASE TYPE	AGE AT RELEASE	NUMBER TAGGED	ADJPOSE ONLY	NOT MARKED	TOTAL RELEASE
63/36/38	1985	On-Station	Sub-Yearling	98,650	468		99,118
63/36/39		On-Station	Sub-Yearling	49,325	468		49,793
63/36/40		On-Station	Sub-Yearling	49,325	468		49,793
63/36/41		On-Station	Sub-Yearling	49,325	468		49,793
63/36/42		On-Station	Sub-Yearling	49,325	468		49,793
63/36/33		Transport	Sub-Yearling	49,112	366		49,478
63/36/34		Transport	Sub-Yearling	49,112	366		49,478
63/36/35		Transport	Sub-Yearling	49,112	366		49,478
63/36/36		Transport	Sub-Yearling	49,113	367		49,480
63/36/37		Transport	Sub-Yearling	49,112	366		49,478
63/41/56		On-Station	Yearling	152,479	1,075		153,554
63/41/59		Transport	Yearling	156,036	470		156,506
63/42/59	1986	On-Station	Sub-Yearling	126,076	2,836		128,912
63/42/61		On-Station	Sub-Yearlina	125.570	2.824		128,394
63/42/62		Transport	Sub-Yearling	127,715	1,030		128,745
63/44/01		Transport	Sub-Yearling	128,283	1,034		129,317
63/44/11		On-Station	Yearling	58,735	236		58,971
63/44/13		On-Station	Yearling	58,970	237		59,207
63/44/07		Transport	Yearling	60,523	213		60,736
63/44/08		Transport	Yearling	60,281	212		60,493
63/52/14	1987	On-Station	Sub-Yearling	124,345	374	839,682	964,401
63/52/16		On-Station	Sub-Yearlina	124.394	374	840,018	964,786
63/52/11		Transport	Sub-Yearling	122,850	2,125	21,246	146,221
63/52/13		Transport	Sub-Yearling	122,899	2,125	21,254	146,278
63/47/52		On-Station	Yearling	57,756	58		57,814
63147156		On-Station	Yearlina	57,594	58		57,652
63/47/50		Transport	Yearling	59,608	299		59,907
63/47/55		Transport	Yearling	59,609	299		59,908

Table 3. (continued).

TAG CODE	BROOD YEAR	RELEASE TYPE	AGE AT RELEASE	NUMBER TAGGED	ADIPOSE ONLY	NOT MARKED	TOTAL RELEASE
63/02/26	1988	On-Station	Sub-Yearling	113,193	2,075	18,244	133,512
63/02/28		On-Station	Sub-Yearling	113,285	2,076	18,244	133,605
63/52/04		Transport	Sub-Yearling	116,935	3,121	21,208	141,264
63/52/07		Transport	Sub-Yearling	117,168	3,128	21,207	141,503
63/02/35		On-Station	Yearling	55,922	496		56,418
63/02/37		On-Station	Yearling	56,597	502		57,099
63/02/31		Transport	Yearling	58,988	458		59,446
63/02/32		Transport	Yearling	58,989	458		59,447
63/55/44	1989		Sub-Yearling	123,640	3,662		127,302
63/55/47			Sub-Yearling	123,233	3,601		126,834
63/55/49			Sub-Yearling	118,104	4,716		122,820
63/55/50			Sub-Yearling	119,941	4,787		124,728
63/41/43	1990		Sub-Yearling	111,784	562		112,346
63/41/60			Sub-Yearling	110,748	1,345		112,093
63/40/12			Yearling	23,954	113		24,067
63/40/13			Yearling	21,137	268		21,405
63/41/18			Yearling	218,110	1,515		219,625
63/41/20			Yearling	202,674	2,566		205,240
63/42/09			Yearling	104,820	792		105,612
63/42/10			Yearling	98,374	560		98,934

We applied cohort analysis to the CWT recovery data to estimate harvest rates of Snake River fall chinook. Methods for cohort analysis have been described by the Pacific Salmon Commission (PSC 1988); Schaller and Cooney (1992); and TAC (1993). Cohort analysis is simply an expanded inventory or accounting procedure of the number of fish from a given CWT release group that were caught in ocean fisheries, were caught in river fisheries, escaped to spawn in the river, or escaped to spawn in a hatchery. Additionally, estimates of the number of fish that died between each of these events are incorporated into the accounting. The procedure begins with the oldest age group, assuming that all fish remaining alive at age 5 mature. An occasional fish shows up at age 6 and these fish are grouped with age 5 fish in the analysis. An inventory of the population of fish alive at the beginning of age 5 is estimated by the following equation:

Equation 2. Generalized equation *for cohort* analysis.

Alive(S) = Ice Harbor Trap(5)lCFl + Hatvhery(5)/CF2 + Spawn(5)/CF3 + River Catch(5) + Ocean Catch(5)

<u>where</u>

Ice Harbor Trap(S) = number of age 5 fish trapped at Ice Harbor for brood atLyons Ferry Hatchery

Hatchery(S)	= number of age 5 fish spawned in the hatchery
Spawn(5)	= number of age 5 fish spawning in the river
CFl	= Conversion Factor for interdam loss to Ice Harbor Dam
CF2	= Conversion Factor for interdam loss up to the hatchery
CF3	= Conversion Factor for interdam loss to Lower Granite Dam

River Catch(5) = number caught at age 5 in any river fishery
Ocean Catch(5) = number caught at age 5 in the ocean

Conversion factors were calculated from the stock accountability database, and those calculations are discussed in a later section of this report. A similar calculation to the above equation can then be made for the population alive at the beginning of age 4 by starting with the number alive at age 5 and expanding for an assumed overwinter survival between age 4 and 5 of 90%. Those fish that remained in the ocean after age 4 are added to the inventory equation for age 4, similar to the equation for age 5 given above. This process can be successively repeated for each younger age, through age 2. Ovetwinter survival rates of fish remaining at sea are assumed by fisheries agencies to be as follows:

Equation 3. Overwinter ocean survival fates.

- age5 =age4 (0.90)
- age4 = age3 (0.60)
- age 3 = age2 (0.70)

We included additional levels of accounting to the cohort procedure described above such ?hat harvest rates could be estimated for each sex at each age, and above versus below Bonneville Dam. Sex was not reported for all CWT recoveries, so we assumed the sex ratio at each age among CWT recoveries for which sex was determined was representative of all other CWT's at that age (see Appendix 1). We assumed that the age 2 population, prior to maturation of jacks, was composed of 50% males and 50% females.

Fish spawned in Lyons Ferry Hatchery were obtained from three sources: swim-ins to the hatchery, fish trapped at Ice Harbor Dam, and fish trapped at Lower Granite Dam. Fish from these sources had to pass over different number of dams, so they probably suffered different levels of passage mortality. To account for this, CWT's recovered from each of these sources had to be expanded for different conversion rates. This was easy for 1991 and 1992 returns, because fish taken from each location were held separately in those years. Prior to 1991, fish obtained from different locations were mixed together for holding at Lyons Ferry Hatchery, so that when the CWT's were recovered, it was unknown which location the fish came from (Table 4). Because we do know the total number of fish that came from each location, we assumed that CWT's came from each location according to the proportion of the broodstock obtained from that location. This assumption appears reasonable, because Busack (1991) found that the stock composition of fish trapped at Ice Harbor was similar to the stock composition of fish that swam in to Lyons Ferry Hatchery and that were trapped at Lower Granite Dam. No jacks were trapped at Ice Harbor Dam (<60cm), so all age 2 fish in the hatchery were swim-ins. Only jacks were taken at Lower Granite prior to 1991 (Table 4), and those fish were not held for brood, so the CWT composition of jacks from Lower Granite was maintained separately. Recovery data for Lyons Ferry CWT's used in this analysis are presented in Table 5.

We found that trapping of adipose-CWT marked fall chinook at Lower Granite Dam provided a reasonably dependable database for estimating natural spawning of LFH fall chinook in the Snake River. Several attempts (including radio tagging, SCUBA surveys, and remote underwater video surveys) to discover spawning in the tailraces of Snake River dams have indicated that relatively few fish spawn in these areas. We assembled the mark-sampling data at Lower Granite Dam and developed estimates of the number of CWT fish from each group that passed Lower Granite (Table 6). We used the estimates developed by WDFW of fall chinook stock composition at Lower Granite Dam to estimate the total number of LFH stock that passed the dam to spawn naturally. Next, we estimated how many of those fish belonged to each CWT group based on the proportion with that code of Lyons Ferry stock spawned at the hatchery (Table 6). This procedure indicated that naturally spawning fish composed a small proportion of the escapement of CWT fish.

Method 3: Comparison to URB Harvest Rates Estimated by Methods 1 & 2.

In order for URB chinook to serve as a surrogate for SRB chinook, the URB chinook should be caught at the same time and place in the Columbia River as SRB chinook. Because CWT fall chinook from Priest Rapids Hatchery are used to represent URB fall chinook by fisheries agencies and for the PSC model (PSC 1988) we compared the timing of harvest in Zone 6 for CWT chinook from Priest Rapids Hatchery to that of CWT chinook from Lyons Ferry Hatchery. We found that harvest timing for the two stocks matched closely (Figure 1), even for two broods (1984 and 1986) that did not overlap each other in the years that age 4 and 5 fish returned (age 5 fish from the 1984 brood returned in 1989). Given that harvest timing is the same for the two stocks, it follows logically that harvest rates at a given age would be the same. Harvest rates should only be compared for a given age or size range, because the proportion of jacks (jacks have low vulnerability to gill nets) tends to differ between the two stocks (Cramer and Neeley 1993). Since these two URB stocks, have such similar harvest patterns, it is likely that other URB stocks also pass through the fishery at the same time.

Table 4. Summary of mark-sampling procedures and locations for Snake River fall chinook, 1964-1993. Data are from personal communication, B. Bugert, WDFW, Wenatchee.

YEAR	ICE HARBOR DAM TRAP	LYONS FERRY HATCHERY	LOWER GRANITE DAM TRAP
1984	Age by size (adults > 61cm).	No swim-ins	
1985	Age by size (adults > 61cm).	Swim-ins held/spawned with trapped fish	Trapped 50% of marked run < 56cm
		First year of adult swim-ins	Age by size (adults > 55cm).
1986	Age by size (adults > 61cm).	Swim-ins held/spawned with trapped fish	Trapped 25% of the marked run < 56cm
			(attempted SO%, but late).
			Age by size (adults > 55cm).
1987	Age by size (adults > 61cm).	Swim-ins held/spawned with trapped fish	Trapped 49% of the marked run < 56cm
			Age by size (adults > 55cm).
1988	Age by size (adults > 61cm).	Swim-ins held/spawned with trapped fish	Trapped 53.2% of the marked run < 56cm
			Age by size (adults > 55cm).
989	Age by size (adults > 61 cm).	Swim-ins held/spawned with trapped fish	NO trapping activities for fall chinook
			Age by size (adults > 55cm).
990	Age by size (adults > 61cm).	began separating by trapping source	First yr. adults trapped. Only CWT salmon
			trapped. Trapped 50% of CWT's adults
			(Total of 50 Chinook seen)
			Age by size (adults > 55cm).
991	Age by size (adults > 61cm). Only marked	Separated by trapping source	Trapped 39% CWT's
	fish trapped at Ice harbor.		Age by size (adults > 55cm).
992	Age by size (adults > 61cm). Only marked	Separated by trapping source	Started trapping for all CWT/ad clips
	fish trapped at Ice harbor.		Trap 85% CWT (goal 100%)
			Age by size (adults > 55cm).
993	Age by size (adults > 61cm). Only marked	Separated by trapping source	Trapped 100% CWT/ad clips
	fish trapped at Ice harbor.		Age by size (adults > 55cm).

Dam counts and LGR trap classify adults as > 55cm, fish trapped at IHD and LFH > 6lcm are considered adults (Busack, C 1991; B. Bugert, Personal communication)

Table 5. Recovery data on CW chinook from Lyons Ferry Hatchery (LHF), as reported in the PSMFC database, for 1964436 brood code groups that were released on station as subyearlings. RCATCHB = Catch below Bonneville, RCATCHA = Catch above Bonneville.

CWT Code	Brood	LFH6	IHTRAPG	LGRTRAP6	RCATCHB	RCATCHA	OCATCH6
				Age 6			
633226	1984	0	0	0	0	0	0
633227	1984	0	0	0	0	0	3
633228	1984	0	0	0	0	0	0
Total-64		0	0	0	0	0	3
633638	1985	1	0	0	0	0	0
633639	1985	0	0	0	0	0	0
633640	1985	0	0	0	0	0	0
633641	1985	0	0	0	0	0	0
633642	1985	1	0	0	0	0	0
Total-65		2	0	0	0	0	0
634259	1986	0	0	0	0	0	0
634261	1986	0	0	0	0	0	0
Total-66		0	0	0	0	0	0

CWT Code	Brood	LFH5	IHTRAP5	LGRTRAP5	RCATCHB	RCATCHA	OCATCH5
				Age 5			
633226	1984	2	3	1	2	19	0
633227	1984	1	1	0	3	10	10
633228	1984	1	2	0	3	6	17
Total-64		4	6	1	a	35	27
633638	1985	2	5	0	2	4	8
633639	1985	2	4	1	2	8	0
633640	1985	1	2	1	0	9	5
633641	1985	1	1	0	0	8	9
633642	1985	1	2	0	0	2	23

Total-85		7	14	2	4	31	45
634259	1986	7		0	4	6	27
634261	1986	10		0	7	2	12
Total-86		17	0	0	11	6	39

CWT				Age 4			
Code	Brood	LFH4	IHTRAP4	LGRTRAP4	RCATCHB	RCATCHA	OCATCH4
633226	1984	4	15	2	14	53	81
633227	1984	4	15	2	37	66	112
633228	1984	5	17	2	34	39	82
Total-84		13	47	6	85	158	275
633638	1985	3	4	1	2	18	67
633639	1985	2	4	1	15	15	28
633640	1985	2	3	1	0	29	10
633641	1985	2	3	1	11	15	15
633642	1985	2	4	1	7	16	17
Total-85		11	18	5	35	93	137
634259	1986	12	24	3	8	62	104
634261	1986	9	19	2	2	66	102
Total-86		21	43	5	10	128	206

CWT				Age 3			
Code	Brood	LFH3	IHTRAP3	LGRTRAP3	RCATCHB	RCATCHA	OCATCH3
633226	1984	19	18	6	25	43	132
633227	1984	18	18	6	21	34	90
633228	1984	23	22	8	9	17	102
Total-84		60	58	20	55	94	324

633638	1985	0	2	0	0	0	10
633639	1985	2	5	0	0	4	5
633640	1985	1	2	0	4	3	7
633641	1985	1	2	0	0	0	5
633642	1985	1	5	0	6	0	8
Total-85		5	16	0	10	7	35
634259	1986	9	14	3	10	5	81
634261	1986	7	11	3	0	19	92
Total-86		16	25	6	10	24	173

CWT				Age 2			
Code	**Brood**	**LFH2**	**IHTRAP2**	**LGRTRAP2**	**RCATCHB**	**RCATCHA**	**OCATCHZ**
633226	1984	13	0	24	10	3	22
633227	1984	12	0	13	12	2	13
633228	1984	9	0	19	4	6	19
Total-84		34	0	56	26	11	54
633638	1985	4	0	3	0	0	8
633639	1985	1	0	5	0	0	5
633640	1985	3	0	4	0	0	0
633641	1985	7	0	2	0	0	0
633642	1985	3	0	3	0	4	0
Total-85		18	0	17	0	4	13
634259	1986	7	0	0	3	0	3
634261	1986	17	0	1	0	4	
Total-86		24	0	1	3	4	3

Table 6. Data used to estimate the number of LFH fall chinook with CWT's that spawned naturally above Lower Granite Dam. About half of the adipose marked fall chinook observed at Lower Granite Dam have been trapped each year beginning in 1990 and used for brood stock at LFH.

Recovered Tags					Estimates -- LFH Stock							
DATE	Tag code	Brood Year	Sample Size (N)		LFH Stock Sampled for CWT		Total Natural Spawners		% CWT code in Sample	% CWT code Trapped@ LGR		Est. CWT Natural Spawners
1987	63/32/26	1984	37	a	3570	e	575	i	0.0104	0.049	j	6
	63/32/27	1984	36	a	3570	e	575	i	0.0101	0.049	j	6
	63/32/28	1984	45	a	3570	e	575	i	0.0126	0.049	j	7
	63/36/33	1985	1	a	3570	e	575	i	0.0003	0.49	j	0
	63/36/34	1985	1	a	3570	e	575	i	0.0003	0.49	j	0
	63/36/36	1985	1	a	3570	e	575	i	0.0003	0.49	j	0
	63/36/37	1985	3	b	3570	e	575	i	0.0008	0.49	j	0
	63/36/38	1985	4	a	3570	e	575	i	0.0011	0.49	j	0
	63/36/39	1985	1	a	3570	e	575	i	0.0003	0.49	j	0
	63/36/40	1985	3	a	3570	e	575	i	0.0008	0.49	j	0
	63/36/41	1985	7	a	3570	e	575	i	0.0020	0.49	j	1
	63/36/42	1985	3	a	3570	e	575	i	0.0008	0.49	j	0
		Total	**142**									20
1988	**63/32/26**	**1984**	19	a	2062	e	192	i	0.0092	0		2
	63/32/27	1984	19	a	2062	e	192	i	0.0092	0		2
	63/32/28	1984	21	a	2062	e	192	i	0.0102	0		2
	63/36/34	1985	3	a	2062	e	192	i	0.0015	0.0532	j	0
	63/36/35	1985	2	a	2062	e	192	i	0.0010	0.0532	j	0
	63/36/36	1985	1	b	2062	e	192	i	0.0005	0.0532	j	0
	63/36/37	1985	5	b	2062	e	192	i	0.0024	0.0532	j	0
	63/36/38	1985	2	a	2062	e	192	i	0.0010	0.0532	j	0
	63/36/39	1985	7	a	2062	e	192	i	0.0034	0.0532	j	1
	63/36/40	1985	2	a	2062	e	192	i	0.0010	0.0532	j	0
	63/36/41	1985	3	a	2062	e	192	i	0.0015	0.0532	j	0
	63/36/42	1985	6	a	2062	e	192	i	0.0029	0.0532	j	1

Table 6. (Continued)

Recovered Tags					Estimates -- LFH Stock							
DATE	**Tag code**	**Brood Year**	**Sample Size (N)**		**LFH Stock Sampled for CWT**		**Total Natural Spawners**		**% CWT code in Sample**	**% CWT code Trapped@ LGR**		**Est. CWT Natural Spawners**
	63/42/59	1986	7	a	2062	e	192	i	0.0034	0.532	j	0
	63/42/61	1986	17	a	2062	e	192	i	0.0082	0.532	j	1
	63/42/62	1986	64	a	2062	e	192	i	0.0310	0.532	j	3
	63/44/01	1986	68	a	2062	e	192	i	0.0330	0.532	j	3
		Total	**246**									**15**
1989	63/32/26	**1964**	**5**	a	1403	e	206	i	0.0036	0		1
	63/32/27	1984	1	a	1403	e	206	i	0.0007	0		0
	63/32/28	1984	2	a	1403	e	206	i	0.0014	0		0
	63/36/33	1985	8	b	1403	e	206	i	0.0057	0		1
	63/36/34	1985	8	b	1403	e	206	i	0.0057	0		1
	63/36/35	1985	9	b	1403	e	206	i	0.0064	0		1
	63/36/36	1985	8	b	1403	e	206	i	0.0057	0		1
	63/36/37	1985	6	b	1403	e	206	i	0.0043	0		1
	63/36/38	1985	7	b	1403	e	206	i	0.0050	0		1
	63/36/39	1985	6	b	1403	e	206	i	0.0043	0		1
	63/36/40	1985	5	b	1403	e	206	i	0.0036	0		1
	63/36/41	1985	4	b	1403	e	206	i	0.0029	0		1
	63/36/42	1985	6	b	1403	e	206	i	0.0043	0		1
	63/42/59	1986	22	b	1403	e	206	i	0.0157	0		3
	63/42/61	1986	18	b	1403	e	206	i	0.0128	0		3
	63/42/62	1986	62	b	1403	e	206	i	0.0442	0		9
	63/44/01	1986	56	b	1403	e	206	i	0.0399	0		8
		Total	233									**34**
1990	63/36/33	1985	3	a	1000	f	174	i	0.0030	0.5		0
	63/36/34	1985	5	a	1000	f	174	i	0.0050	0.5		0
	63/36/35	1985	3	a	1000	f	174	i	0.0030	0.5		0
	63/36/36	1985	3	a	1000	f	174	i	0.0030	0.5		0
	63/36/37	1985	2	a	1000	f	174	i	0.0020	0.5		0

Table 6. (Continued)

Recovered Tags				Estimates -- LFH Stock				
DATE	Tag code	Brood Year	Sample Size (N)	LFH Stock Sampled for CWT	Total Natural Spawners	% CWT code in Sample	% CWT Code Trapped@ LGR	Est. CWT Natural Spawners
	63/36/38	1985	5 a	1000 f	174 i	0.0050	0.5	0
	63/36/39	1985	6 a	1000 f	174 i	0.0060	0.5	1
	63/36/40	1985	3 a	1000 f	174 i	0.0030	0.5	0
	63/36/41	1985	2 a	1000 f	174 i	0.0020	0.5	0
	63/36/42	1985	1 a	1000 f	174 i	0.0010	0.5	0
	63/42/59	1986	34 a	1000 f	174 i	0.0340	0.5	3
	63/42/61	1986	26 a	1000 f	174 i	0.0260	0.5	2
	63/42/62	1986	43 b	1000 f	174 i	0.0430	0.5	4
	63/44/01	1986	54 a	1000 f	174 i	0.0540	0.5	5
	63/52/11	1987	1 a	1000 f	174 i	0.0010	0.5	0
	63/52/13	1987	3 a	1000 f	174 i	0.0030	0.5	0
	63/52/14	1987	3 a	1000 f	174 i	0.0030	0.5	0
	63/52/16	1987	6 b	1000 f	174 i	0.0060	0.5	1
	63/52/04	1988	3 a	1000 f	174 i	0.0030	0.5	0
	63/52/07	1988	1 a	1000 f	174 i	0.0010	0.5	0
	63/02/26	1988	3 b	1000 f	174 i	0.0030	0.5	0
	63/02/28	1988	1 a	1000 f	174 i	0.0010	0.5	0
		Total	**211**					**18**
1991	63/36/38	1985	1 c	1272 g	205 i	0.0008	0.39	0
	63/42/59	1986	2 c	1272 g	205 i	0.0016	0.39	0
	63/42/61	1986	3 c	1272 g	205 i	0.0024	0.39	0
	63/42/62	1986	6 c	1272 g	205 i	0.0047	0.39	1
	63/44/01	1986	5 c	1272 g	205 i	0.0039	0.39	0
	63/52/11	1987	3 c	1272 g	205 i	0.0024	0.39	0
	63/52/13	1987	2 c	1272 g	205 i	0.0016	0.39	0
	63/52/14	1987	1 c	1272 g	205 i	0.0008	0.39	0
	63/52/16	1987	2 c	1272 g	205 i	0.0016	0.39	0
	63/52/04	1988	4 c	1272 g	205 i	0.0031	0.39	0
	63/52/07	1988	2 c	1272 g	205 i	0.0016	0.39	0
	63/02/26	1988	2 c	1272 g	205 i	0.0016	0.39	0
	63/02/28	1988	1 c	1272 g	205 i	0.0008	0.39	0

Table 6. (Continued)

Recovered Tags					Estimates -- LFH Stock						
DATE	**Tag code**	**Brood Year**	**Sample Size (N)**		**LFH Stock Sampled for CWT**		**Total Natural Spawners**		**% CWT code in Sample**	**% CWT code Trapped@ LGR**	**Est. CWT Natural Spawners**
	63/55/44	1989	5	c	1272	g	205	i	0.0039	0.39	0
	63/55/47	1989	10	c	1272	g	205	i	0.0079	0.39	1
	63/55/49	1989	6	c	1272	g	205	i	0.0047	0.39	1
	63/55/50	1989	9	c	1272	g	205	i	0.0071	0.39	1
		Total	**64**								6
1992	'63136134	1985	1	d	3233	h	277	h	0.0003	0.85	0
	63/42/59	1986	1	d	3233	h	277	h	0.0003	0.85	0
	63/44/01	1986	1	d	3233	h	277	h	0.0003	0.85	0
	63/52/04	1988	3	d	3233	h	277	h	0.0009	0.85	0
	63/52/07	1988	3	d	3233	h	277	h	0.0009	0.85	0
	63/02/26	1988	6	d	3233	h	277	h	0.0019	0.85	0
	63/02/28	1988	5	d	3233	h	277	h	0.0015	0.85	0
	63/55/44	1989	16	d	3233	h	277	h	0.0049	0.85	0
	63/55/47	1989	17	d	3233	h	277	h	0.0053	0.85	0
	63/55/49	1989	17	d	3233	h	277	h	0.0053	0.85	0
	63/55/50	1989	30	d	3233	h	277	h	0.0093	0.85	0
	63/41/43	1990	17	d	3233	h	277	h	0.0053	0.85	0
	63/41/60	1990	7	d	3233	h	277	h	0.0022	0.85	0
		Total	**124**								**0**

Footnotes:
a) Bugert et al. (1991; Appendix C)
b) PSMFC CWT data base 1993
c) Lyons Ferry swim-ins only Lavoy, L. (1992; Table 2)
d) Lavoy, L. (Personal communication 1993)
e) Bugert et al. (1990; Table 9) represents all age classes
f) Age 36 only Bugert et al. (1991)
g) all ages, swim ins only, Lavoy, L. (1992; Table 5)
h) Lavoy, L. 1993 (Personal Communication; Table 1)
i) Busack (1991; Table 8)
j) Bugert et al. (1988). CWT recoveries at LFH show 10% of age 3 fish were under 55 cm -- the cut-off for trapping

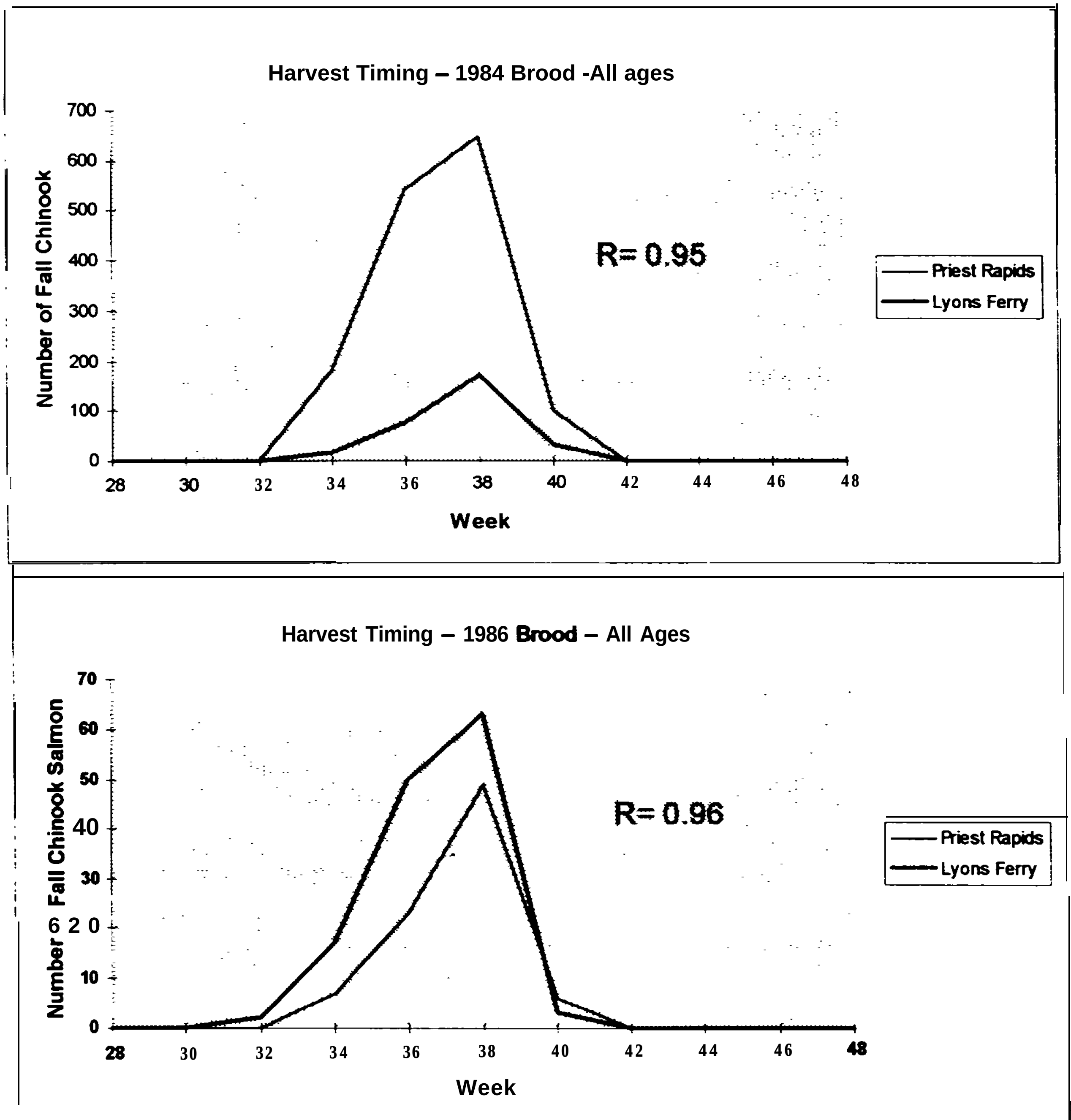

Figure 1. Number of CWT fall chinook (subyearlings) from Lyons Ferry and Priest Rapids hatcheries captured biweekly in the Zone 6 gill net fishery. (Source PSMFC database, Portland, Oregon).

In fact, counts of fall chinook at Columbia River dams indicate that migration timing for all URB stocks combined peaks sharply within a fairly narrow time window that is highly consistent between years (Figure 2). We compared time of passage for fall chinook at The Dalles Dam to that at McNary Dam, and found that passage peaks sharply in early September at both dams and that the difference in peak passage is generally about one week (Figure 2). We chose The Dalles Dam rather than Bonneville Dam so that hatchery fish returning to the Bonneville pool would not be included in the counts. This comparison indicates that fall chinook destined for areas above McNary Dam move quickly through the Zone 6 fishery, and further supports the notion that different URB stocks are exposed to similar harvesting effort and removal rates in Zone 6.

After we had confirmed that the URB and SRB chinook pass through Zone 6 at the same time, we applied methods 1 & 2 above to estimate harvest rates in Zone 6 on URB chinook. Stock accountability data on URB chinook are presented in Table 7. We applied cohort analysis to CWT groups from Priest Rapids Hatchery that were released on station as subyearlings from the 1984-86 broods. Recovery data are presented in Table 8. We used the same CWT groups used by PSC to represent URB chinook in the ocean harvest (PSC 1993). We used the same interdam conversion factors on the CWT data that are used by TAC (personal communication, M. Johnson, CRITFC, Portland). These conversion factors are the same for Bonneville to McNary as was applied to SRB chinook. No other expansion factor was applied for loss of fish above McNary Dam.

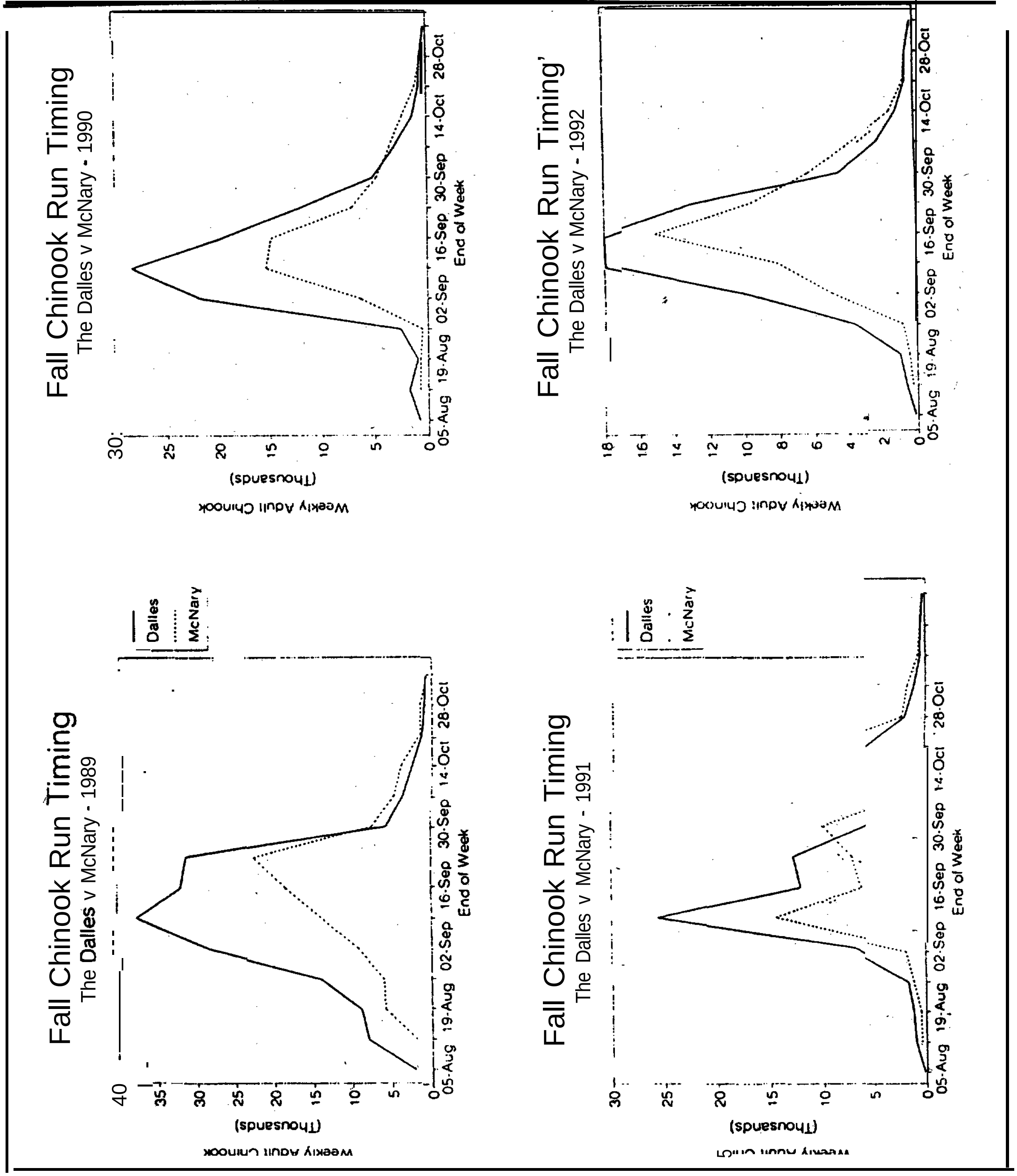

Figure 2. Weekly counts of adult fall chinook (>60 cm) over The Dalles and McNary Dams, 1989-1992 (USACE database, Portland, Oregon).

Table 7. Stock accounting for URB chinook in Zone 6, 1986-1992. Data from TAC reports, 1988-1993, and personal communication, R. Roler, WDFW, Battleground.

Return Year	Bonneville URB Count (a)	Zone 6 Catch (b)					URB Harvest Rate
		LRH	BPH	URB	MCB	Other	
1986	214,050	700	5,700	93,400	5,800		43.6%
1987	303,967	600	1,700	123,300	15,900	300	40.6%
1988	**249,722**	1,900	3,000	125,100	22,100	400	**50.1%**
1989	211,878	0	13,300	98,800	22,100	300	44.6%
1990	131,842	200	7,700	59,200	15,400	400	44.9%
1991	86,681	400	22,800	23,700	6,300	400	27.3%
1992	73,743	200	9,700	13,900	5,100	300	18.8%

(a) 1993 Biological Assessment (TAC 1993, Table 2).
(b) TAC Reports (Table 5, 1984-1986; Table 4, 1987-1992).
(c) Other category represents Rogue River and stray stocks.

Table 8. Recovery data on CWT chinook from Priest Rapids Hatchery (PRH), as reported in the PSMFC database, for 1984-86 brood code groups that were used by PSC to represent URB chinook. RCATCHB = Catch below Bonneville, RCATCHA = Catch above Bonneville.

CWT Code	Brood	Age 6 PRH	Age 6 RC6	Age 6 OC	Age 5 PRH	Age 5 Hanf	Age 5 Othr	Age 5 RCB	Age 5 RCA	Age 5 OC	Age 4 PRH	Age 4 Hanf	Age 4 Othr	Age 4 RCB	Age 4 RCA	Age 4 OC
633221	1984	3	0	12	32	0	0	29	102	131	77	0	0	460	311	317
633222	1984	6	18	4	42	17	0	25	83	158	67	21	2	163	360	323
Total-84		9	18	16	74	17	0	54	185	289	144	21	2	623	671	640
634102	1985	3	0	11	37	79	0	30	112	110	37	17	0	66	168	143
634128	1986	0	0	0	18	21	0	2	25	30	37	0	0	17	75	118
Hanford Wild 634152	1986				120		0	43	67	135	107	0	0	27	95	109

CWT Code	Brood	Age 3 PRH	Age 3 Hanf	Age 3 Othr	Age 3 RCB	Age 3 RCA	Age 3 OC	Age 2 PRH	Age 2 Hanf	Age 2 Othr	Age 2 RCB	Age 2 RCA	Age 2 OC
633221	1984	101	0	3	104	86	211	82	0	0	44	3	7
633222 .	1984	80	0	0	102	160	178	123	29	0	15	0	59
Total-84		181	0	3	206	246	389	205	29	0	59	3	66
634102	1985	28	21		52	37	25	12	0	0	0	0	0
634128	1986	31	0	1	27	25	16	27	21	0	8	0	0
Hanford Wild 634152	1986	20	0	0	12	24	29	24	0	0	32	7	6

Results of Harvest Rate Estimates

Age Specific Differences in Harvest Rate

Harvest rates estimated by all methods (Table 9) indicated that harvest rates were similar between ages 4, 5, and 6, but that harvest rate was substantially reduced at age 3. Harvest rates on age 2 chinook in Zone 6 were almost nonexistent, and harvest rates on age 3 fish were consistently lower than those on age 4 and 5 fish each year (Figure 3). Such was also the finding of Schaller and Cooney (1992). Evidently, the age 3 fish are not fully vulnerable to gill nets, because of their smaller size (see HARVEST SELECTIVITY). Note that all of these methods calculate harvest rate in terms of run size at Bonneville Dam, not at the river mouth. Run size at the river mouth should be used for purposes of allocating catches between Zones 1-6, but the run size at Bonneville should used to evaluate the proportion of the surviving run that is harvested in Zone 6.

Because harvest rates at age 3 are lower than those at age 4-6, inclusion of age 3 fish in the calculation of average harvest rate causes the average harvest rate to be less than is actually experienced by most adults. TAC (1993) included age 3 fish in their calculation of harvest rates for the 1993 Biological Assessment of fall commercial fisheries. Use of this reduced average is misleading, because most females mature at ages 4 and 5. Thus, the productivity of the population is reduced by a greater proportion than the average harvest rate for ages 3-5 indicates. It would be more appropriate for harvest managers to use harvest rate at age 4 or the average for ages 4-6.

Table 9. Alternative estimates of harvest rates in zone 6 at each age on Snake River fall chinook, 1986-1992. Harvest data for SRB's and URB's, supplied by Ron Roler, WDFW Lab, Battleground, Washington.

	Estimation Method			
	ACCOUNT	COHORT	ACCOUNT	COHORT
AGE/YEAR	SRB	LFH	URB	PRH
AGE 3				
1986	18.0%	--	--	--
1987	25.7%	26.3%	22.2%	54.3%
1988	14.5%	18.3%	18.5%	42.4%
1989	15.0%	22.9%	24.2%	41.4%
1990	14.5%	--	2.3%	--
1991	8.6%	--	16.9%	--
1992	5.2%	--	13.3%	--
AGE4				
1986	0.0%	--	--	--
1987	42.5%	--	48.1%	--
1988	41.1%	59.3%	53.9%	79.7%
1989	41.2%	60.6%	45.8%	73.8%
1990	43.4%	51.5%	48.0%	62.7%
1991	23.3%	--	18.4%	--
1992	9.9%	--	23.9%	--
AGE5				
1986	71.8%	--	--	--
1987	0.0%	--	41.7%	--
1988	46.6%	--	47.9%	--
1989	48.0%	69.1%	47.2%	64.7%
1990	42.1%	43.3%	46.7%	43.8%
1991	28.2%	13.0%	32.6%	33.3%
1992	22.4%	--	12.7%	–

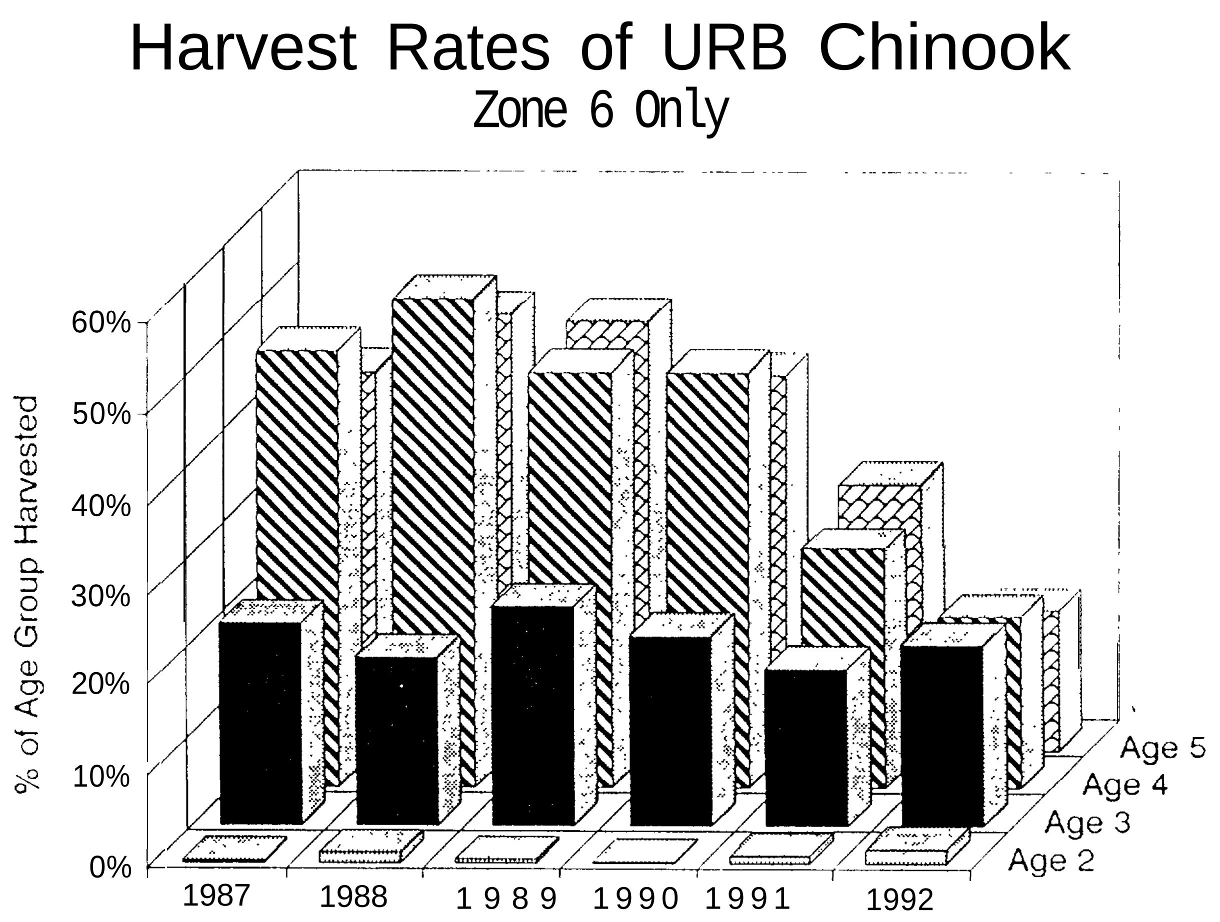

Figure 3. Age specific harvest rates in Zone-6 each year, 1987-1992, on URB fall chinook, as estimated by the stock accounting method. Data are from Table 9.

The misleading effect of including age 3 fish in the catch is most apparent from the sex specific harvest rates calculated by cohort analysis of CWT recoveries (Table 10). Fish returning at age 3 were 60% to 80% males (subyearling releases only) (Figure 4). We confirmed with the CWT data that the high percentage of males at age 3 was similar in the catch to that in the spawning escapement (Figure 4). Females that matured at age 3 were consistently larger than males (Figure 5), and the harvest rate on age 3 females was greater than that on age 3 males in each of the three broods analyzed (Figure 6). This difference in harvest rates between the sexes at age 3, given that 60-80% of age 3 fish are males, further increases the bias in estimated harvest rate on females when age 3 fish are included in the calculation of average harvest rate.

The age and sex-structured cohort analysis that we completed demonstrated that, as a consequence of including age 3 fish in the calculation of average harvest rate, the average harvest rate is always less than that on age 4 fish, generally by 10 to 15 percentage points (Figure 7). This is an important difference when planning harvest regulations, because most females mature at age 4. Further, age 3 fish have composed a highly variable proportion of the run entering the Columbia River (Figure 8), so the inclusion of age 3 fish in the average harvest rate estimated by TAC (1993) each year would have reduced the average by varying amounts between years. One can see from Figure 8 that the downward bias in harvest rates, with regard to females, would have been especially great in 1986 when the run was dominated by age 3 fish.

Table IO. Age and sex specific maturity (MATR) and ocean harvest rate (OHAR) of Lyons Ferry chinook, 1984-86 broods, as estimated by cohort analysis of CWT groups released on station as subyearlings.

CWT Code	Brood	Release	SURV2	Male MATR2	Female MATR3	Male MATR3	Female MATR4	Male MATR4	OHAR2	OHAR3	OHAR4	OHAR5
633226	1984	78417	0.0062	0.248	0.220	0.534	0.746	0.752	0.045	0.238	0.374	0.000
633227	1984	78064	0.0055	0.195	0.160	0.454	0.801	0.813	0.030	0.155	0.396	0.332
633228	1984	78504	0.0052	0.226	0.195	0.454	0.764	0.767	0.046	0.199	0.358	0.547
		Mean:	0.0057	0.223	0.192	0.481	0.770	0.777	0.041	0.197	0.376	0.293
Total-84		Sum:		0.224	0.189	0.481	0.773	0.779	0.041	0.197	0.377	0.293
633638	1985	98650	0.0028	0.145	0.003	0.031	0.586	0.443	0.029'	0.056	0.508	0.290
633639	1985	49325	0.0044	0.164	0.031	0.216	0.687	0.589	0.023	0.037	0.301	0.000
633640	1985	49325	0.0035	0.215	0.043	0.212	0.680	0.597	0.000	0.065	0.140	0.256
633641	1985	49325	0.0034	0.263	0.009	0.106	0.648	0.568	0.000	0.048	0.201	0.437
633642	1985	49325	0.0042	0.181	0.039	0.204	0.556	0.412	0.000	0.060	0.193	0.714
		Mean:	0.0037	0.194	0.025	0.154	0.631	0.522	0.010	0.053	0.268	0.339
Total-85		Sum:		0.188	0.023	0.149	0.630	0.516	0.012	0.053	0.298	0.373
634259	1986	126076	0.0026	0.061	0.086	0.199	0.682	0.672	0.009	0.154	0.337	0.457
634261	1986	125570	0.0027	0.142	0.088	0.211	0.672	0.673	0.000	0.184	0.364	0.228
		Mean:	0.0027	0.102	0.087	0.205	0.677	0.672	0.005	0.169	0.351	0.342
Total-86		Sum:		0.103	0.087	0.205	0.678	0.672	0.004	0.169	0.350	0.349

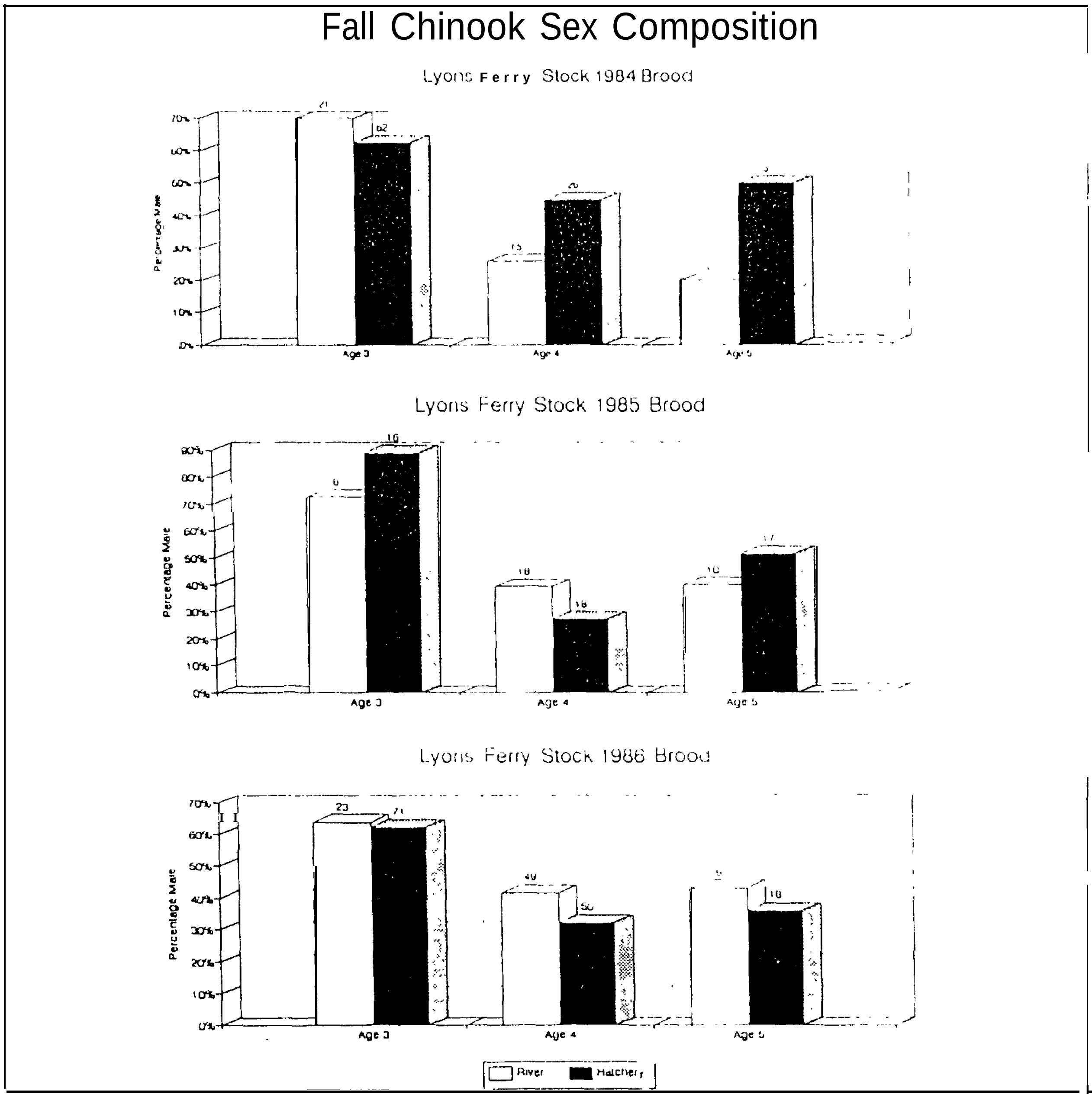

Figure 4. Percentage that males composed at each age of Lyons Ferry fall chinook, as determined from CWTs recovered in the catch (River) and returning to the hatchery. Numbers at the top of each bar are the number of CWT fish for which sex was recorded. All subyearling releases of CWT groups, either on-station or transported, were included. (Source: PSMFC database).

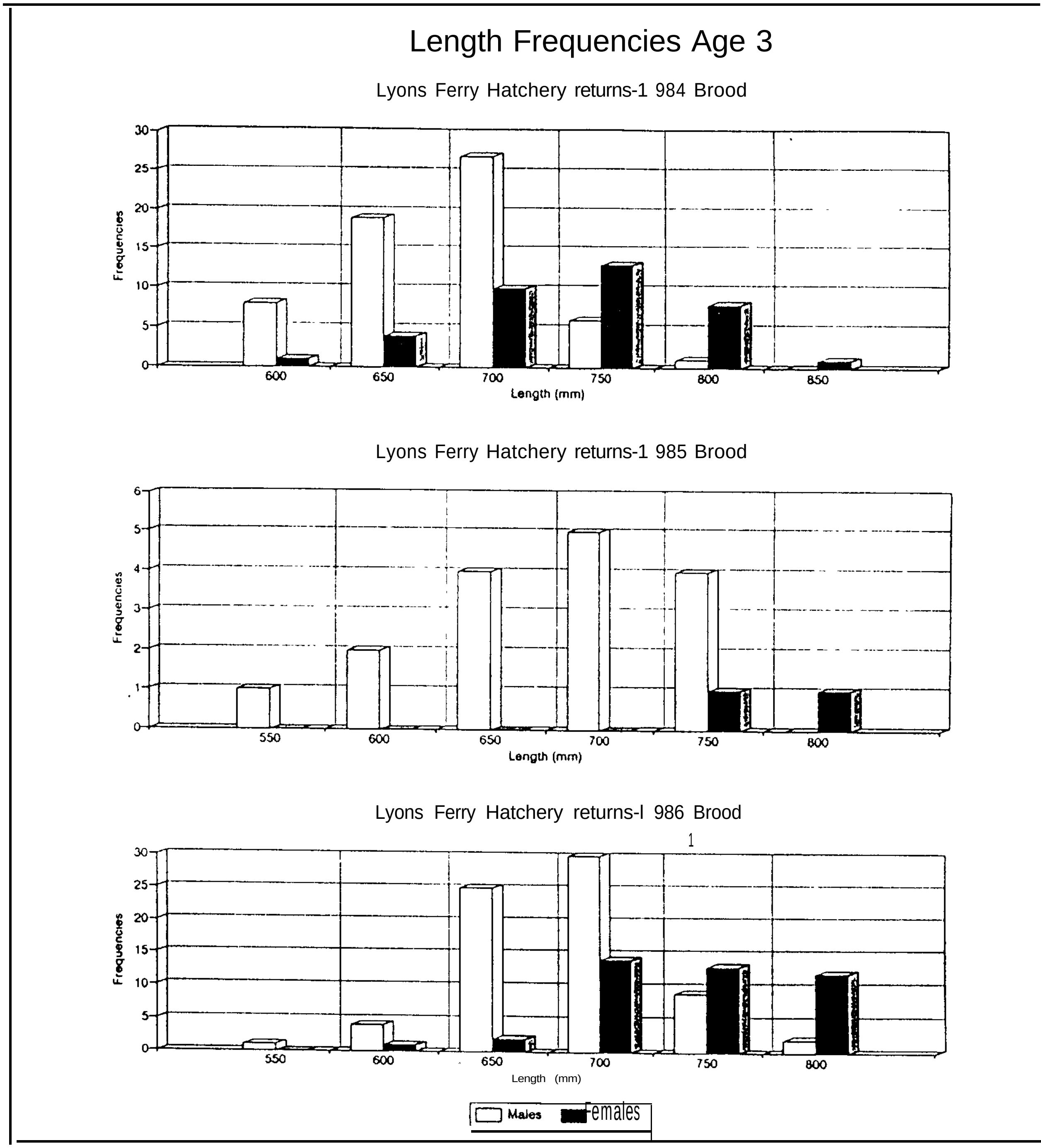

Figure 5. Sex-specific length frequencies at age 3 of CWT chinook from Lyons Ferry Hatchery that were released as subyearlings, either on-station or transported. (Source: PSMFC database)

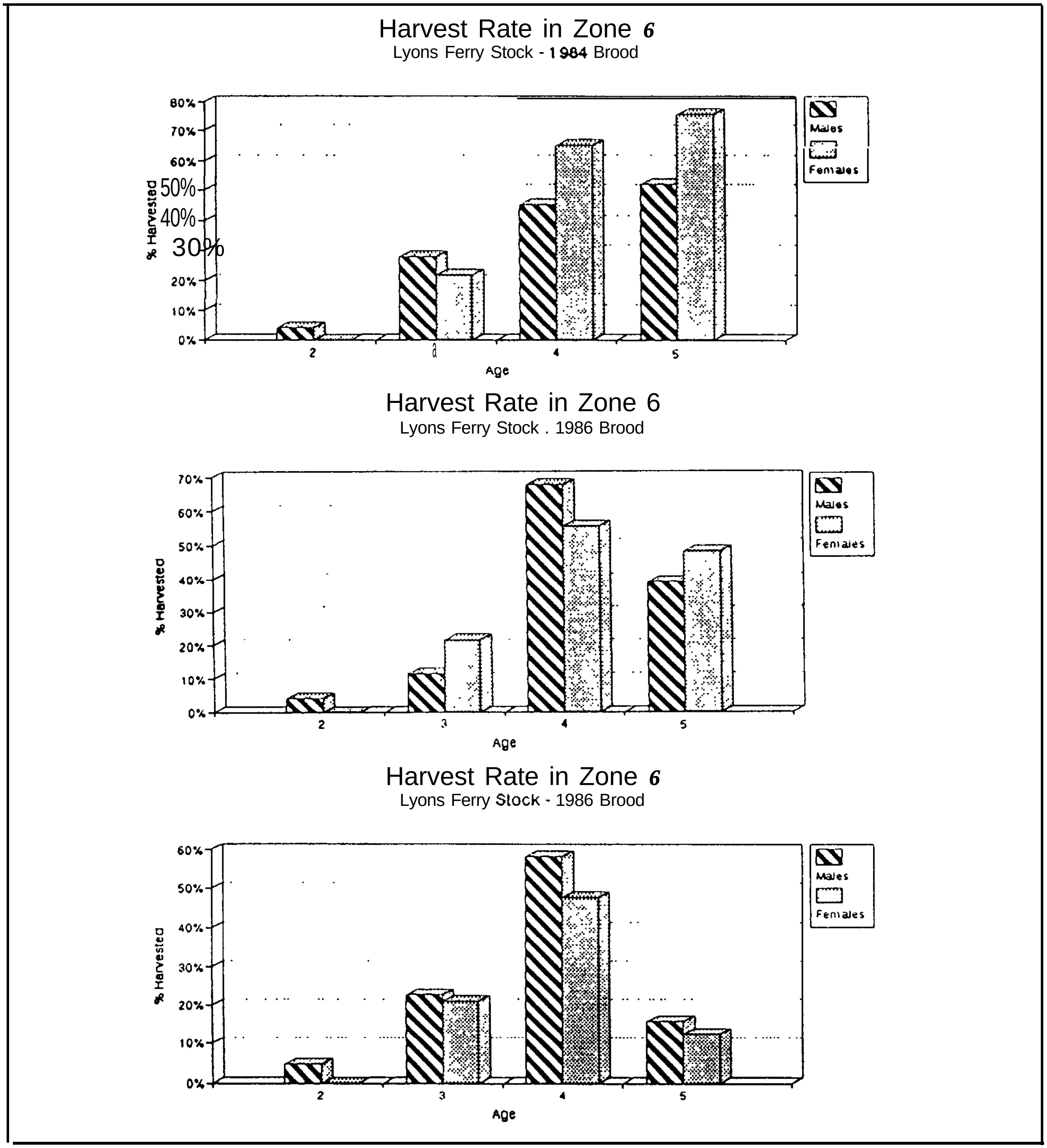

Figure 6. Age and sex-specific harvest rates in Zone 6 of the Columbia River, as estimated by cohort analysis of CWT groups released as subyearlings at Lyons Ferry Hatchery.

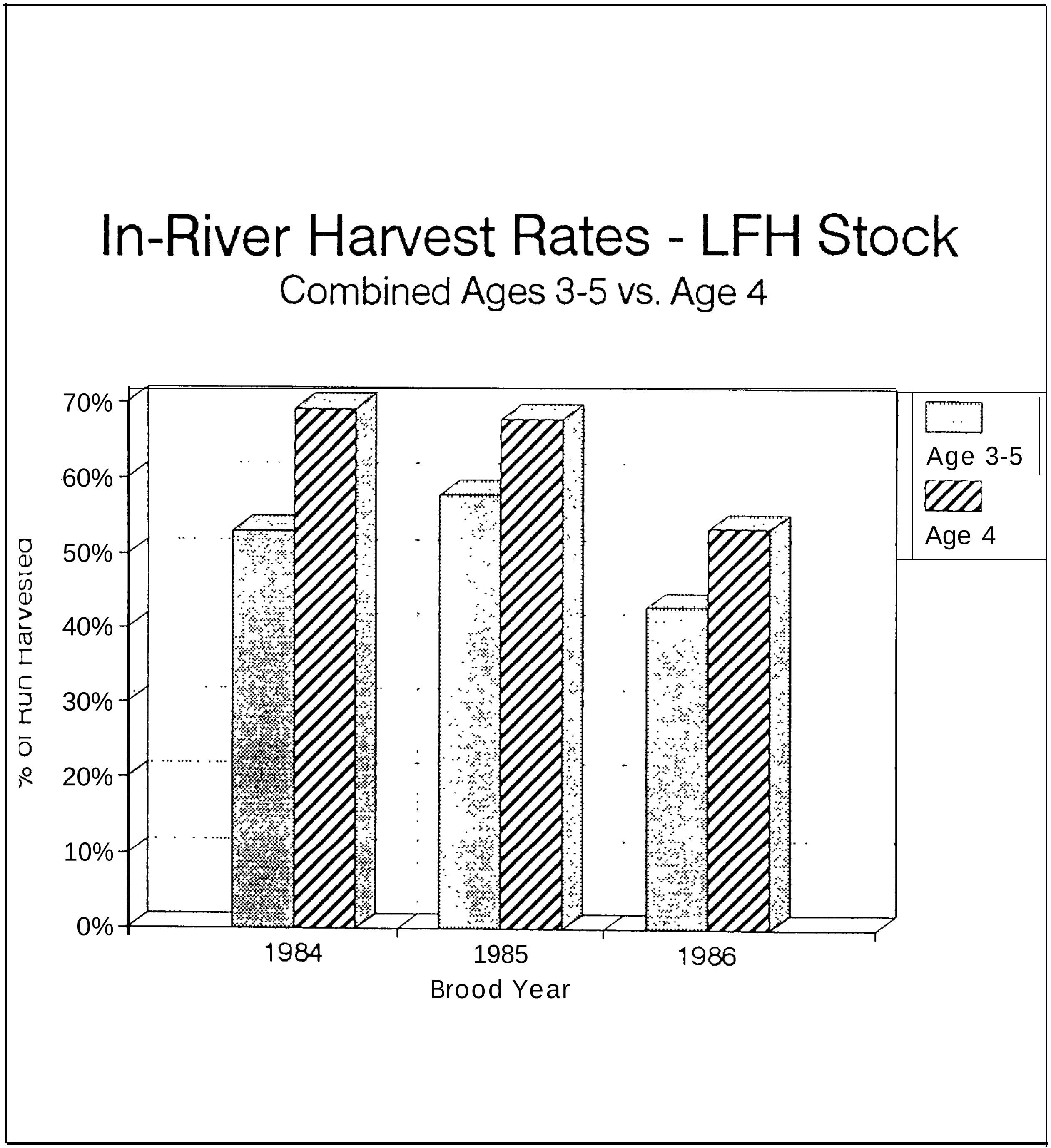

Figure 7. Comparison of harvest rates at age 4 to those for the average of ages 35 for the 1984-86 broods. These rates were estimated by the cohort analysis we performed with CWTs recoveries from subyearling chinook released at Lyons Ferry Hatchery.

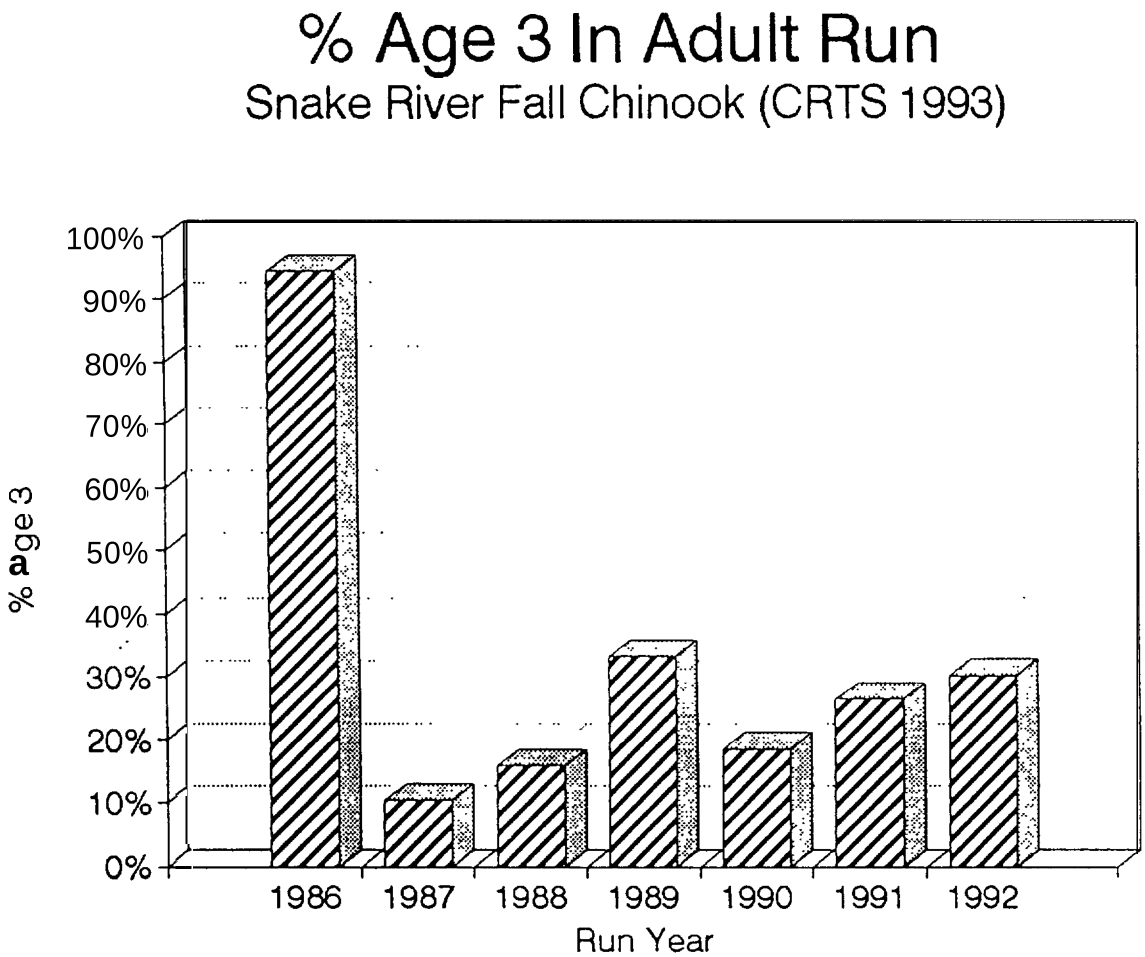

Figure 8. Proportion that age 3 fish composed of the run of Snake River bright fall chinook entering the Columbia River, 1986-1992. (Source: CRTS 1993, p. 23, Table 7).

Differences in Harvest Rate Estimates Between Methods

There were substantial differences between methods in the estimates of harvest rate in Zone 6 for any given year. We restricted the comparisons to harvest rates on age 4 or the average for age 4-6 in order to avoid the bias caused by including age 3. Harvest rates estimated by the stock accountability method were similar between SRB and URB chinook in 1990, but the estimates were slightly higher for URB chinook in 1988 and 1989 (Figure 8). These differences were small enough that they could easily have been produced by sampling errors in the accounting procedure.

TAC (1993) reported that estimated in-river harvest rates on SRB chinook has averaged 83.9% of that on URB chinook during 19861992, and that harvest rates on SRB chinook were estimated to be less than those on URB chinook in every year. The comparison made by TAC included age 3 fish, so we recalculated the comparison using the average stock accounting estimates of harvest rates on age 4-6 fish in Zone 6 alone. Even when restricted to age 4-6 fish, the estimated mean harvest rate on URB chinook remained consistently higher than on SRB chinook (Figure 10). It appears that there is also a systematic bias in the SRB chinook accounting to over expand the escapement numbers, which results in an under estimate of harvest rate on SRB chinook. See Table 13 and the associated discussion. We found no substantive evidence that harvest rates should differ between URB and SRB chinook. Therefore, we conclude that the consistent differences cited by TAC (1993) are an artifact of bias in the expansions of sampling data. The harvest rates estimated on URB chinook should be accepted as the best estimates of harvest rate on SRB chinook also, because URB chinook destined for the mid Columbia composed the vast majority of the landings in Zone 6 and the escapement over McNary Dam. Therefore, errors in accounting for SRB chinook would have had little influence on the URB estimate, since the SRB chinook composed such a small portion of the run (see Figure 17).

Harvest rates estimated by cohort analysis were substantially higher than those estimated by stock accountability, particularly in the case of Priest Rapids fall chinook (Figure 9). The substantial difference in harvest rates estimated by cohort analysis compared to those by stock accounting indicates that there are probable biases in the expansions of CWT recoveries from spawners.

The high harvest rates, estimated by cohort analysis for Priest Rapids chinook (see Figure 9), appear to be unreasonable compared to the more direct estimates derived from stock accountability data. Again, the major difference in the calculation procedure between Priest Rapids and Lyons Ferry chinook is the use of prespawning mortality factors above McNary Dam. Mortality in the Columbia River above McNary Dam is assumed to be zero, while mortality in the Snake River (in the form of conversion factors) is assumed to be 1 O-l 5% between McNary and Ice Harbor dams and **16-29%**

per pool above Ice Harbor Dam. The net result is that CWT's recovered in the Snake River get expanded by a factor of about two times more than CWT's recovered in the mid Columbia. Such a difference does not seem logical, and the aberrant harvest rates estimated for Priest Rapids chinook using the assumption of no mortality above McNary Dam demonstrates that the assumption is inappropriate. We determined by iteration that a 50% mortality had to be assigned to the Priest Rapids fish above McNary Dam before the estimated harvest rates came into line with those estimated by stock accountability. It is conceivable that such a large prespawning mortality would go undetected, because the reservoir behind McNary Dam itself serves as the holding area for chinook during the two months between peak passage at McNary (mid September) and peak spawning at Priest Rapids Hatchery (late November). Water temperature during this time of year can be stressful and 27-37% of the fish have hooking or net wounds (see Catch Expansions). The bias caused by the assumption of no prespawning mortality in the mid Columbia River does not affect the calculation of harvest rates on Snake River fall chinook.

As further evidence of the need to account for mortality above McNary Dam, we found that harvest rates estimated from cohort analysis of CWTs for wild fall chinook in the Hanford reach were much lower than those for hatchery fish (Table II). Higher prespawning mortality on hatchery fish than on wild fish is a common occurrence, and would explain the disparity in harvest rates estimated for hatchery and wild fish.

Probable Sources of Bias and Error

Because there are many data inputs to this accounting process, there are many possible sources of bias or error in the calculations. These include errors in:

- assumed mortality during river passage,
- natural spawner expansions,
- catch expansion,
- assumed mortality from non-landed catch,
- assumed mortality rates in the ocean.

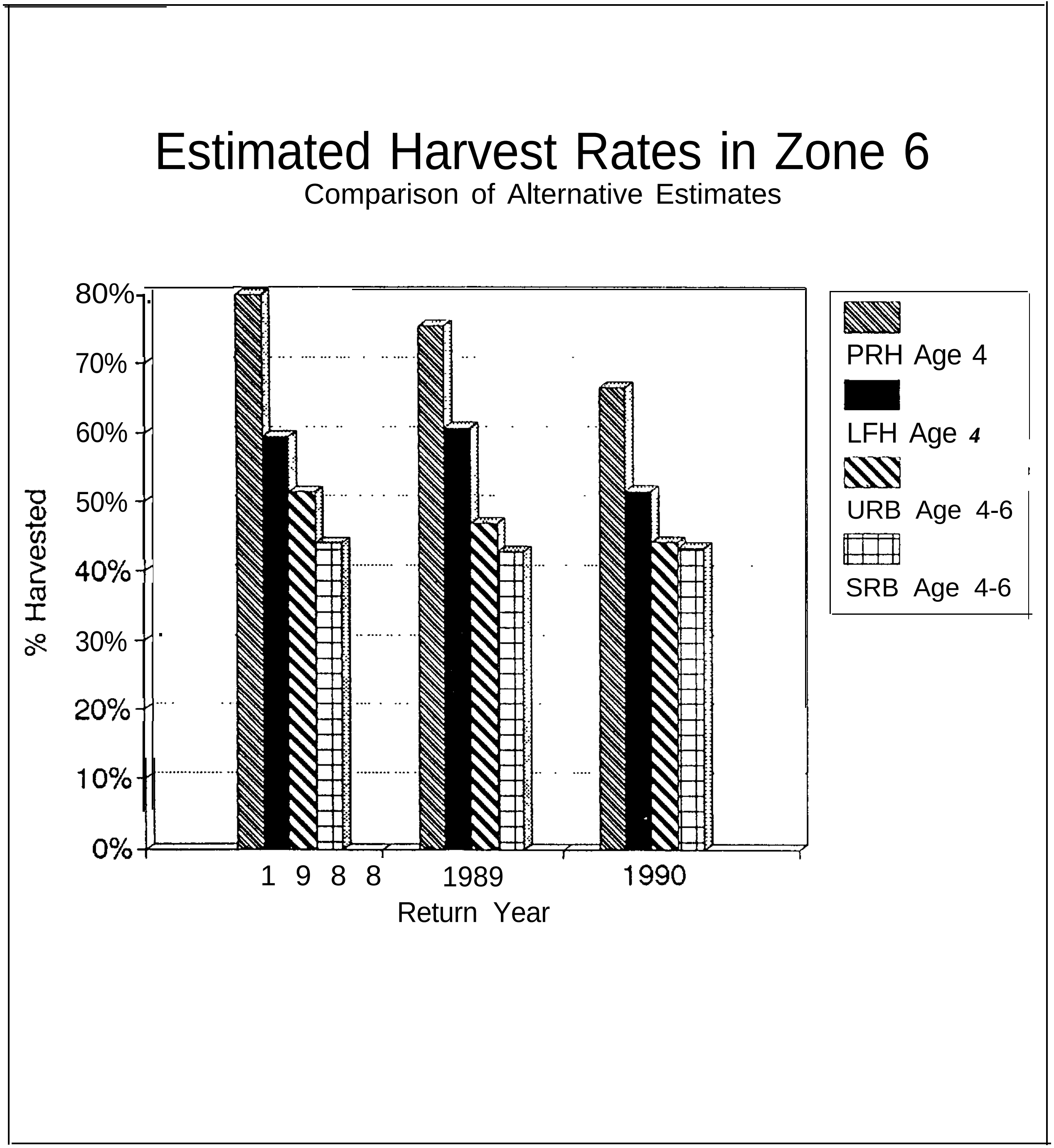

Figure 9. Comparison of four estimates of age specific harvest rates in Zone 6 on Snake River fail chinook.

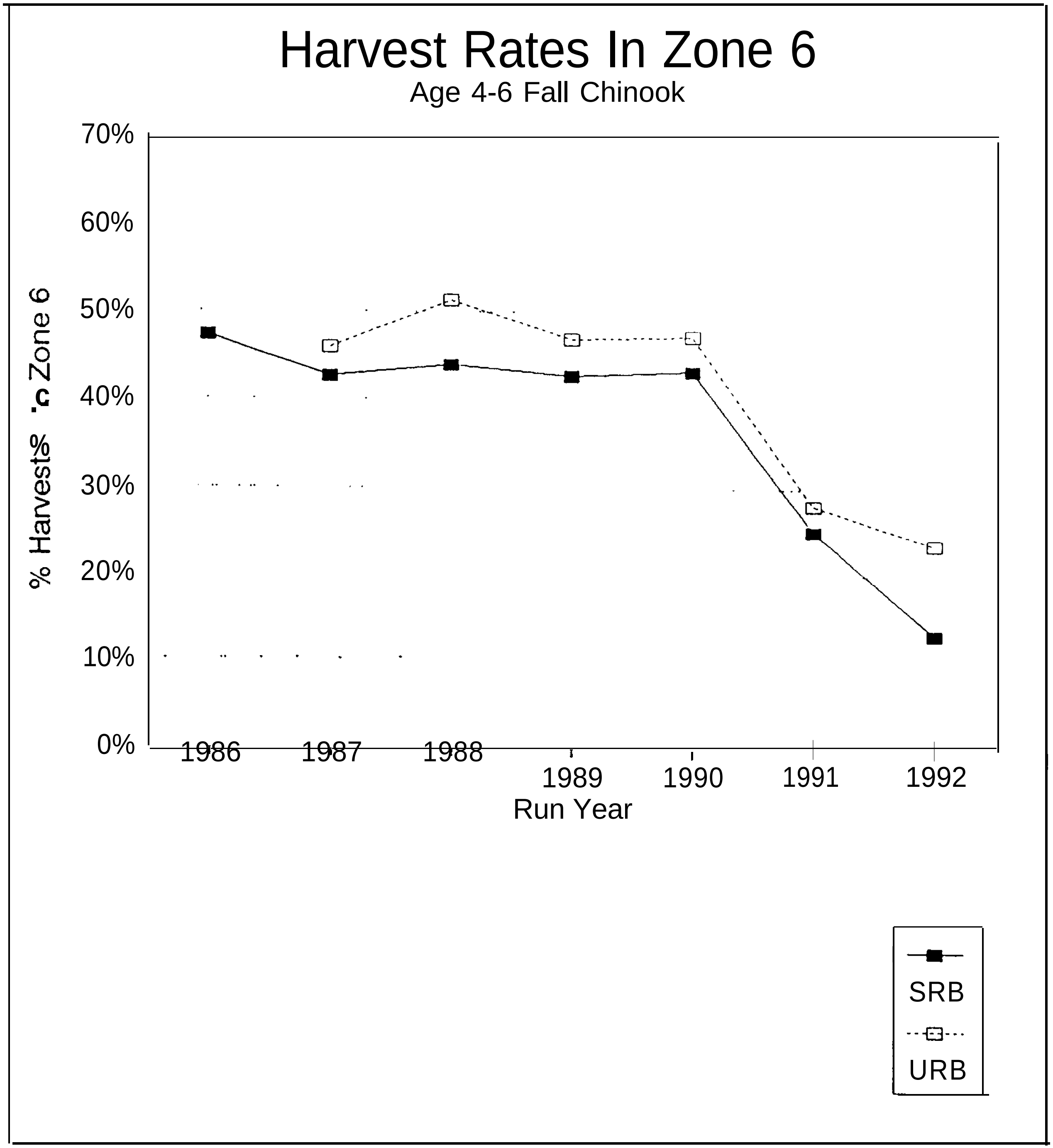

Figure 10. Comparison between URB and SRB chinook of mean harvest rate on age 4-6 chinook in Zone 6, as estimated by the stock accounting method. Data from Table 9.

Table 11. Age specific harvest rates in the Columbia River for Priest Rapids fall chinook as estimated by cohort analysis of CWT groups released on station as subyearlings. Based on data in Table 8.

CWT Code	Brood	Age 2 River Total	Aae 3 Below Bonnvl	Aae 3 Above Bonnvl	Aae 3 River Total	Age 4 Below Bonnvl	Age 4 Above Bonnvl	Age 4 River Total
633221	**1984**	**0.363**	**0.339**	0.423	0.619	0.541	0.798	0.907
633222	**1984**	**0.089**	0.290	0.640	0.744	0.265	**0.796**	0.850
Total-84		**0.208**	0.312	0.543	0.686	0.425	**0.797**	0.883
634102	**1985**	**0.000**	0.374	0.424	0.639	0.225	0.738	**0.797**
634128	**1986**	**0.140**	0.309	0.414	0.595	0.124	0.627	0.673
Hanford Wild 634152	**1986**	0.613	0.206	0.520	0.619	0.107	0.424	0.486

CWT Code	Brood	Age 5 Below Bonnvl	Age 5 Above Bonnvl	Age 5 River Total	Age 3-6 River Total
633221	**1984**	0.171	0.725	0.772	0.823
633222	**1984**	0.126	0.584	0.637	0.782
Total-84		0.147	0.647	**0.699**	0.804
634102	**1985**	0.105	0.438	**0.497**	0.647
634128	**1986**	0.026	0.333	0.350	0.568
Hanford Wild 634152	**1986**	0.163	0.303	0.417	0.467

Assumed Mortality During River Passage

The most probable cause of these differences in the harvest rates estimated by stock accounting and cohort analysis is that the prespawning mortality rates assumed for each method are substantially different. The stock accountability method requires the least assumptions about prespawning mortality, because it uses counts at Ice Harbor Dam to assess the SRB population size and it uses McNary Dam fish counts to assess the URB population size. Thus, dam conversion factors, which represent prespawning mortality and any unaccounted spawning, are applied only from Bonneville to Ice Harbor for the SRB's, and from Bonneville to McNary Dam for the remaining URB's. Although the use of counts at Ice Harbor Dam minimizes the number of conversion factors that must be applied to SRB escapement, it adds another bias from the fallback rates that are known to be high at Ice Harbor Dam (Mendel et al. 1993). Bias caused by fallback will be discussed later.

Because the primary difference in the stock accountability and CWT cohort analysis methods is the application of dam conversion rates, we will first describe how these conversion rates are calculated and how they are applied to the different estimates of harvest. The overall conversion rate for Snake River fall chinook has been calculated as the product of three components; one for the Columbia River up to McNary Dam, one for McNary Dam to Ice Harbor Dam, and one for a per-dam-rate in the Snake River. These conversion rates represent the proportion of fish that can be accounted for between dams by subtracting catch and turn-offs from the count at the downstream end of the river section. Loss is assumed to be similar between each dam in the Columbia River or the Snake River, so the single-dam conversion factor can be calculated for a given river stretch by taking the n_{th} root of the conversion for the stretch, where n is the number of reservoirs the fish passed through. Conversion equations used by the fisheries agencies are as follows:

Equation 4. Conversion rate from the Columbia River mouth fo McNary Dam.

Conversion = Cube root of [McNary ChF count/(Bonneville URB count - Zone 6 URB catch - Deschutes turnoff)]

Equation 5. Conversion rate for each *Snake River* dam.

Conversion = Square root of [LGR ChF count/(Lower Monumental ChF count - LFH swim ins - Tucannon and Palouse spawning estimates)]

Equation 6. Conversion rate from McNary Dam to Ice Harbor Dam.

Conversion = Average of single pool rates for Columbia and Snake rivers.

As shown in the equation for Bonneville to McNary, this estimate is developed from the same stock accountability database that TAC uses to estimate harvest rates (see Table 5). Conversion rates calculated by TAC (1995) are listed in Table 12. These are the conversion rates that we used in all three methods of estimating harvest, but they were applied in different ways in each method.

Table 12. Conversion rates used by the fisheries agencies for Snake River fall chinook (from U.S. v. Oregon TAC 1995).[a]

Year	Bonneville to McNary Rate (b)	Single Columbia River Project Rate (c)	McNary to Ice Harbor Rate (d)	Single Snake River Project Rate (e)	Rate for 3 Snake R Projects (f)	Bonneville to Lower Granite Rate (g)
1986	0.9930	0.9976	0.8608	0.7239	0.3794	0.3243
1987	0.8877	0.9611	0.8611	0.7610	0.4408	0.3369
1988	0.9760	0.9919	0.8494	0.7068	0.3531	0.2928
1989	0.9040	0.9669	0.8687	0.7706	0.4575	0.3593
1990	0.8287	0.9393	0.8665	0.7938	0.5002	0.3592
1991	0.7747	0.9184	0.8746	0.8307	0.5732	0.3883
1992	0.8999	0.9655	0.9013	0.8371	0.5867	0.4759
1993	0.8305	0.9400	0.9370	0.9341	0.8150	0.6342
1994	0.8355	0.9419	0.8998	0.8577	0.6311	0.4744
Avg. (86-90)	0.9179	0.9714	0.8613	0.7512	0.4262	0.3345
Avg. (91-94)	0.8352	0.9415	0.9032	0.8649	0.6515	0.4932
Avg. (86-94)	0.8811	0.9581	0.8799	0.8018	0.5263	0.4050

Footnotes:

a) Data developed by WDFW Columbia River Lab.
b) McNary FCH count / (Bonneville URB count - Z6 harvests - Deschutes escapement).
c) Cube root of Bonneville to McNary rate.
d) Average of Columbia River single project and Snake River single project rates.
e) Square root of ((Lower Granite FCH count) / (Lower Monumental FCH count -
f) Lyons Ferry swim-ins - Tucannon and Palouse escapements).
g) Cube of single project Snake River rate.
h) Product of Bonneville-McNary, McNary-Ice Harbor, and 3 Snake Projects conversion rates.

These conversion rates were involved in the different methods as follows. The stock accountability method applies the Bonneville to McNary conversion factor ($CF_{B\text{-}Mc}$) to all fish crossing McNary Dam, in order to reconstruct the run at McNary back to the run at Bonneville along with the fish that were caught or turned off between the dams. That is:

Equation 7. Stock accountability calculations.

URB at Bonn. = URB at McNary/$CF_{B\text{-}Mc}$ + Zone 6 catch of URB's + Deschutes turnoffs

SRB at Bonn. = SRB at McNary/$CF_{B\text{-}Mc}$ + Zone 6 catch of SRB's

SRB at McNary = SRB at Ice Harbor/$CF_{Mc\text{-}IH}$

where $CF_{Mc\text{-}IH}$ = Conversion Factor for McNary to Ice Harbor

The cohort analysis that we calculated with WIT's applied different conversion factors, depending on where the fish was recovered. Rather than estimating the total escapement of a given tag code by expanding the fish sampled at Ice Harbor Dam to the total run over Ice Harbor, we estimated the escapement by summing the expanded CWT recoveries from each component of the escapement. For example, the cohort analysis calculates the number of fish alive at the beginning of age 5 (ALIVE (5)) as follows:

Equation 8. Escapement of age 5 fish.

Alive(5) = Ice Harbor Trap(5)/CF1 + Hatchery(5)/CF2 + Spawn(5)/CF3 + River Catch(5) + Ocean Catch(5)

where

Ice Harbor Trap(S) = number of age 5 fish trapped at Ice Harbor for brood at Lyons Ferry Hatchery

Hatchery(S) = number of age 5 fish spawned in the hatchery

Spawn(5) = number of age 5 fish spawning in the river

CF1 = Conversion Factor for interdam loss to Ice Harbor Dam

CF2 = Conversion Factor for interdam loss up to the hatchery

CF3 = Conversion Factor for interdam loss to Lower Granite Dam

River Catch(5) = number caught at age 5 in any river fishery
Ocean Catch(5) = number caught at age 5 in the ocean

We assumed that escapement included three components: fish that were trapped at Ice Harbor Dam for brood stock, fish that swam in to Lyons Ferry Hatchery, and fish that spawned naturally above Lower Granite Dam. We estimated the number of CWT's that were in each component based on the sampling of each component. Because these components had passed different numbers of dams in the Snake River, we applied different conversion rates to the different escapement components as follows:

Equation 9. Formulae for conversion rates applied to escapement components.

Fish Removal Point	Conversion Factor
Ice Harbor Dam	3 Columbia pools x McNary-IH pool
Lyons Ferry Hatchery	3 Columbia pools x McNary-IH pool x 2 Snake pools
Lower Granite Dam	3 Columbia pools x McNary-IH pool x 3 Snake pools

This method of accounting for escapement of CWT's passing Ice Harbor Dam resulted in a substantially lower estimate of the number of CWT's reaching Ice Harbor than was estimated by simply expanding the sample at Ice Harbor to the dam count. A form of this latter method was employed by PSC in their cohort analysis of CWT's from Lyons Ferry Hatchery, and their estimates of CWT's at Ice Harbor Dam can be compared to those that we derived (Table 13). The PSC estimates of CWT's at Ice Harbor Dam are 8-34% lower at age 2 than ours, 50-100% higher age 3 than ours, and 3-36% higher at ages 4 and 5 than ours. The method used by PSC for age 2 fish was similar to ours, but they applied only a one pool conversion factor for fish reaching Lyons Ferry Hatchery, while we applied a two pool conversion factor. The method used by PSC for age 3-5 fish assumed that all marked fish counted at Ice Harbor Dam stayed above Ice Harbor Dam and were represented by the ***CWT's*** recovered at Lyons Ferry Hatchery, either from fish trapped at Ice Harbor or from swim ins (personal communication, M. Johnson, CRITFC representative to PSC, Portland). PSC found that the number of swim ins to Lyons Ferry Hatchery during 1990-I 992 averaged 31.4% of the fish allowed to pass upstream of Ice Harbor Dam. Therefore, they assumed in all previous years that 31.4% of all CWT's allowed to pass Ice Harbor Dam swam in to Lyons Ferry

Hatchery and were recovered there. Because CWT's were expanded directly to the total count of marked fish at Ice Harbor Dam, there was no need to apply conversion factors above Ice Harbor Dam, as we did.

The comparison in Table 13 of the estimated number of CWT's at Ice Harbor Dam demonstrates that the assumptions in one or both of these methods is inaccurate. It turns out that the method used by PSC produces a harvest rate estimate closer to the stock accountability estimate than our method (see Interdam Loss). Recall that the cohort method we used produced a higher estimate of harvest rate in Zone 6 than actually observed in Zone 6. Therefore, it is probable that our method under estimated spawning escapement. The bias in our method had to come from under estimating the number of naturally spawning fish, which we assumed were all above Lower Granite Dam. The estimates that we used of spawners that were trapped at Ice Harbor or swam in to Lyons Ferry Hatchery were equal to or greater than those used by PSC. However, we found that PSC did overestimate the number of age 3 fish that would have reached Ice Harbor Dam, because they used a biased estimate of the size distribution of age 3 fish. Only fish > 55 cm were trapped at Ice Harbor Dam, and PSC assumed that only 25% of age 3 CWT's were large enough to qualify as adults (>55 cm). However, the PSC assumption was based on data from fish released as yearling smolts (personal communication, M. Johnson, CRITFC, Portland). The code groups we are working with here were released as subyearlings and 75% to 90% of the age 3 fish were > 55cm at return (Figure 11).

Estimates of conversion rates in the Snake River may be biased low by the lack of accounting for spawning in the tailraces of mainstem dams. Spawning was documented with underwater video in deep water in the tailraces of Little Goose and Lower Granite Dam during the fall of 1994 (personal communication, D. Dauble, PNW Lab, Richland, Washington). Eggs have previously been found in gravel dredged below Lower Monumental Dam. If the fish spawning in these deep water areas tend to have the same stock and age composition as the fish trapped at Ice Harbor and swimming in to Lyons Ferry Hatchery, then the existence of tailrace spawners has no effect on the conversion factor for Snake River reservoirs. It is likely this is the case, since our assumption that all Lyons Ferry strays passed over Lower Granite Dam resulted in an under estimate of spawning escapement. The number of fish spawning in deep water areas has not been estimated, but it appears to be small, so any bias caused to conversion factors is probably small.

A factor that causes a slight under estimate of harvest rate in all of the methods we used is that the numbers of fish landed above Bonneville Dam are not expanded for inriver mortality prior to the time they were caught. Fish caught in Zone 6 had to cross up to three Columbia dams before they were captured. We believe it is inconsistent to assume that fish crossing McNary Dam have suffered mortality below that point, but that fish caught within Zone 6 have not.

In order to account properly for interdam loss prior to capture in Zone 6, landings and CWT recovery data would have to be maintained separately for each reservoir. Prior to 1990, catches in the Zone 6 fishery were not reported according to the reservoir in which they were sold to a commercial buyer, but that information has been recorded each year beginning in 1990. There is a possibility that fish reported as purchased by a buyer in one pool may have been captured in a different pool, however, interviews with buyers and fishermen indicate that such occurrences represent a tiny portion of the catch (personal communication, D. Swartz, ODFW, Clackamas). We examined the number of Lyons Ferry CWT's from subyearling release groups that were recovered in each of these pools and found that the catch distribution remained fairly constant between years (Figure 12). These data indicate that fish landed in Zone 6 had passed a weighted average of 1.7 dams. If we assume that the average distribution of catches between pools in Zone 6 was similar during 1990-I 992 to other years, then we can apply the single Columbia dam conversion rate raised to the 1.7 power as the conversion rate for catch. Because the single dam conversion rates in the Columbia River are near 1 .0, the application of this conversion rate to the Zone 6 catch (which is generally about one third of the in-river run) only increases the run size by one or two percent. Thus, the bias caused by ignoring a conversion factor for the Zone 6 catch is inconsequential.

Table 13. The number of CWT chinook from Lyons Ferry Hatchery that passed Ice Harbor Dam at each age, as estimated by the cohort method documented in this report -- compared to the method used by PSC. PSC estimates are from personal communication, M. Johnson, CRITFC, Portland).

CWT		Number at Ice Harbor							
		Age 2		Age 3		Age 4		Age 5	
Code	Brood	Cohort	PSC	Cohort	PSC	Cohort	PSC	Cohort	PSC
633226	1984	88	81	64	95	29	38	9	10
633227	1984	57	51	63	92	29	38	3	4
633228	1984	67	63	80	115	33	42	4	6
Total-84		212	195	207	302	90	118	15	20
633638	1985	14	12	2	5	11	14	8	10
633639	1985	13	13	9	18	10	12	9	3
633640	1985	14	13	4	5	9	10	6	13
633641	1985	17	11	4	8	9	8	3	3
633642	1985	12	11	7	15	10	12	4	10
Total-85		70	60	26	51	48	56	29	39
634259	1986	14	10	36	56	49	54	10	10
634261	1986	37	24	29	46	37	35	14	24
Total-86		51	34	65	102	86	89	25	34

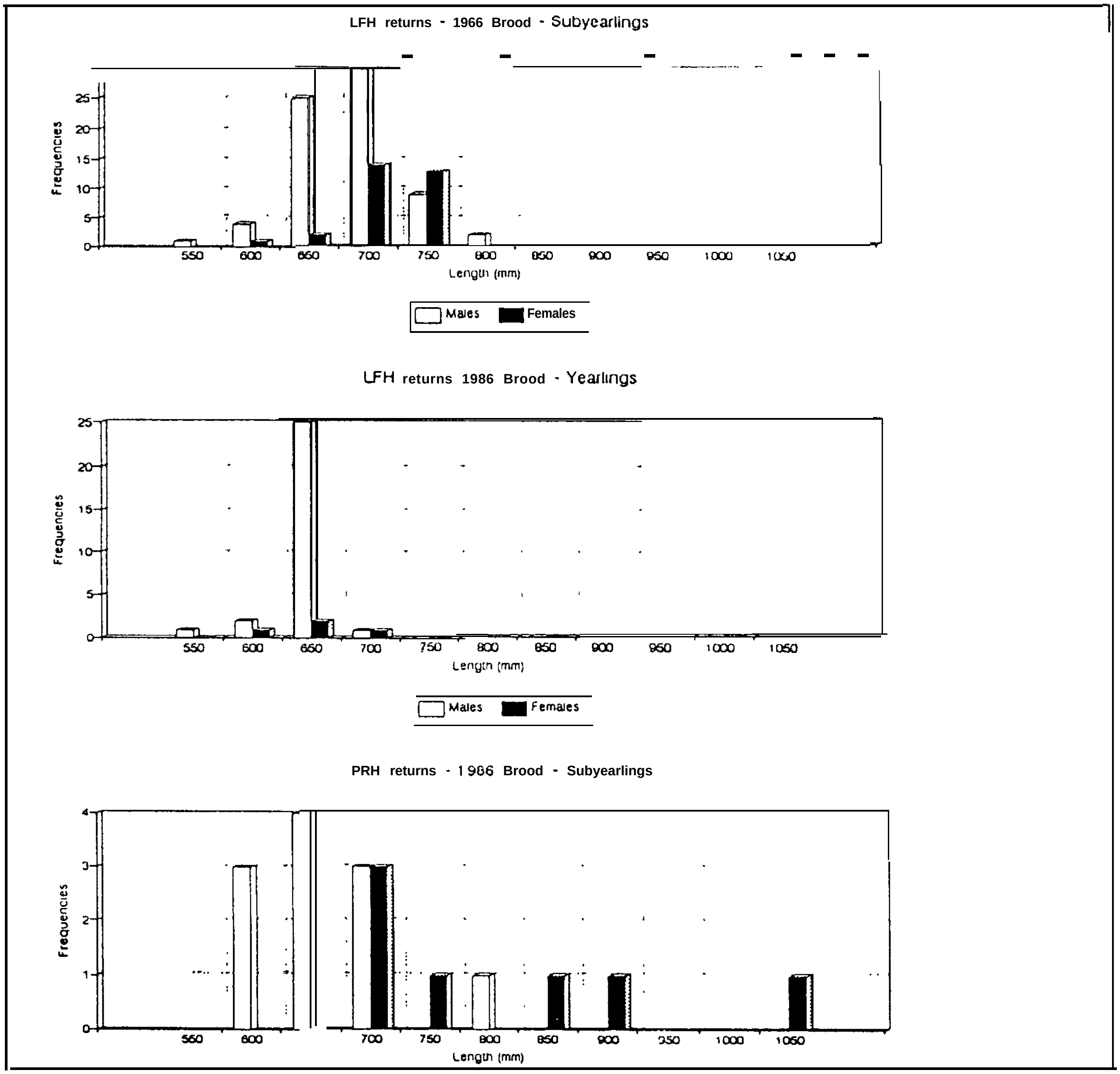

Figure 11. Length frequency at hatchery return of age 3 chinook from the 1986 brood that were CWT marked. {Upper graph -- fish that were released as subyearlings from Lyons Ferry Hatchery; middle graph -fish that were released as yearlings from LFH; bottom graph -fish that were released as subyearlings from Priest Rapids Hatchery}.

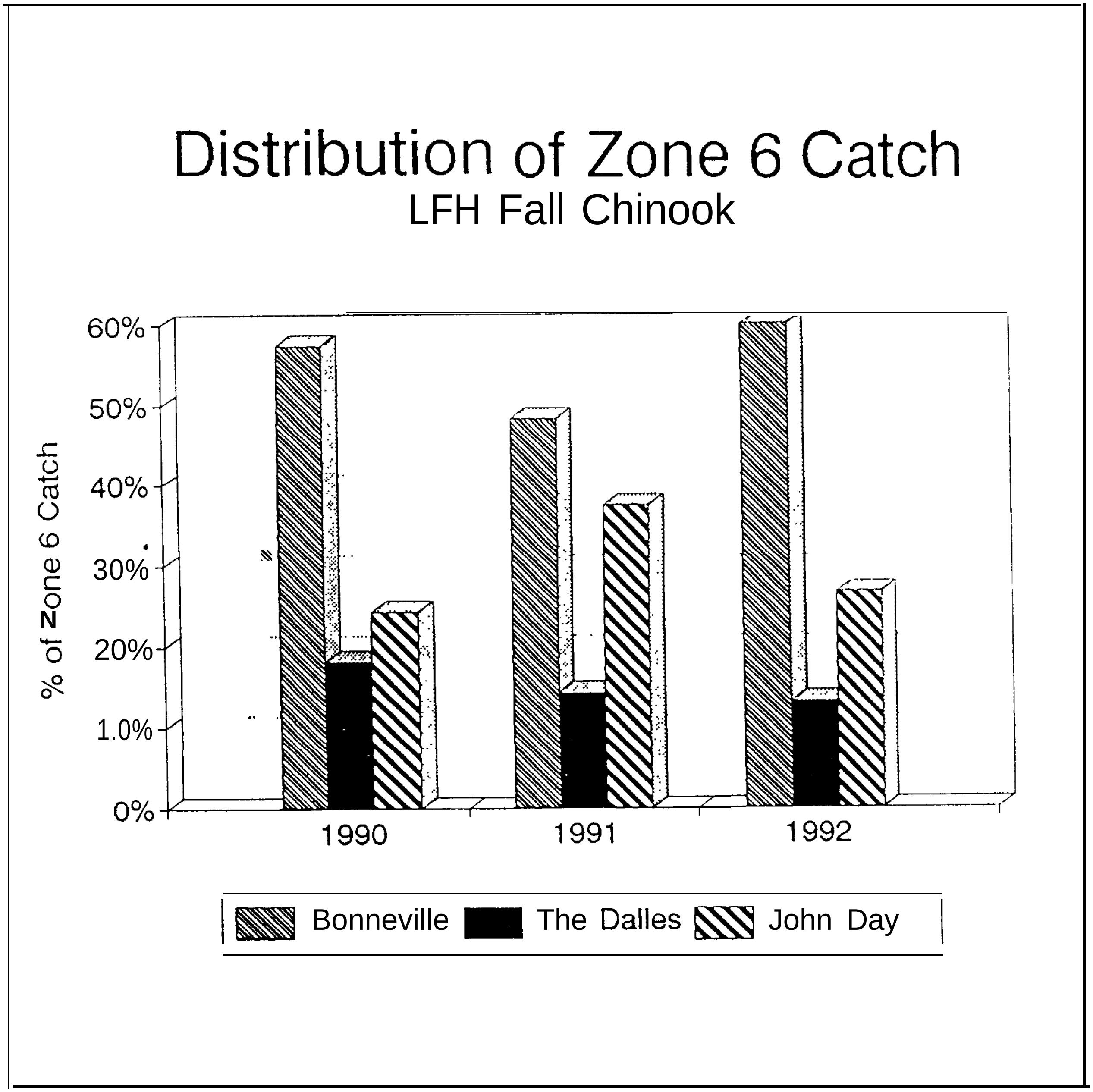

Figure 12. Distribution of landings in Zone 6 of Lyons Ferry fall chinook during 1990-1992, as determined from recoveries of CWT's from fish released as subyearlings on station (data are from PSMFC database).

Estimation of Spawning Escapement

We examined the data on fall chinook spawning surveys to determine if strays from Lyons Ferry hatchery were likely to be detected and accounted for. The number of fish which spawned in the hatchery at each age is known with high accuracy, because 100% of fish with adipose fin clips are sampled for CWT's Other locations where spawning may have occurred include other hatcheries, the free flowing Snake River above Lower Granite Dam, tailrace areas below Snake River dams, tributaries to the Snake River, the mid Columbia River, and the Yakima River. We were concerned about the mid Columbia and Yakima rivers, because radio tagging studies with fall chinook during 1992 revealed that many fish which entered the Snake River later dropped back out and spawned in the mid Columbia or in the Yakima River (Mendel et al. 1993). We found that only in the Yakima River is there a lack of sampling data on fall chinook spawning. Few LFH fall chinook have been recovered outside of the Snake River Basin, including in the extensively surveyed mid Columbia and in the numerous hatcheries in the Columbia Basin (Table 14). Therefore, any errors introduced from improper accounting or expansion for fish straying outside the Snake River Basin would be small.

Interdam Loss

The potential for bias in the estimates of interdam loss was a major concern, because the average dam conversion rate applied by TAC (1993) was 0.394 for Bonneville Dam to Lower Granite Dam during 1989-l 992 (Table 12). This equates to an expansion factor of 2.5 for each spawning fish.

Table 14. Total recoveries of Lyons Ferry CWT's in natural spawning areas, 1986-1992. Source: PSMFC database.

Tag Code	Brood Year	Release Type	Year of Recover	Age at Release	Mid-Columbia	Tucannon River	Mainstem Snake River
63/36/36	**1985**	TR	1990	Sub-Yr	1 (a)		
63/44/01	**1986**	TR	1990	Sub-Yr	1 (a)		
63/32/28	**1984**	OS	1988	Sub-Yr		1 (a)	
63/36/33	**1985**	TR	1990	Sub-Yr		1 (a)	
63/36/40	**1985**	OS	1988 1990	Sub-Yr		1 (a)	 1 upr. (b)
63/36/41	**1985**	OS	1989	Sub-Yr		1 (a)	
63/42/59	**1986**	OS	1989 1990	Sub-Yr		1 (a) 1 (b)	
63/42/61	**1986**	OS	1990	Sub-Yr			
63/42/62	**1986**	TR	1990 1991	Sub-Yr		2 (b)	 1 lwr. (a)
63/44/01	**1986**	TR	1990 1991	Sub-Yr			2 upr. (b) 1 lwr.

(a) from tag code listings by BR, YR, and fortnight
(b) from Bugert et al. (1991; Appendix C)

We examined several lines of evidence to determine if these conversion rates truly reflected lost fish, or if they reflected some problem with the dam counts, such as might be caused by fallback and re-ascension. First, we reviewed results of radio tagging studies of adult fall chinook migrations in the Snake River during 1991 and 1992. Second, we used the stock accounting estimate of harvest rate on URB chinook to calculate the escapement of Lyons Ferry CWT's and they compared this estimate to the observed recoveries.

Effects of Fallback

Radio tracking studies were initiated in 1991 to determine the fate of the unaccounted fall chinook between Ice Harbor and Lower Granite dams. These studies (Mendel et al. 1992; Mendel et al. 1993) showed high rates of fallback at Ice Harbor and Lower Granite dams both years. Mendel et al (1993) could not accurately estimate fallback at Ice Harbor Dam, because of bias caused by the tagging process. In 1992 when fish tagged at Ice Harbor Dam were released both above and below the dam, there was a distinct difference in fallback rate between the two groups: 61% released below the dam ended up outside the Snake River, while 34% released above the dam ended up outside the Snake River. During 1991, only seven of 29 fish that were tracked across Ice Harbor Dam continued all of the way past Lower Granite Dam, and only two of those stayed above Lower Granite Dam, while the others fell back. At least three of the five fish that fell back at Lower Granite Dam were found downstream where they likely spawned (2 in the Tucannon River and one in Lyons Ferry Hatchery; Mendel et al. (1992). Mendel et al. (1993) tracked 17 tagged fish across Lower Granite Dam in 1992, but seven fell back, two multiple times.

Other evidence indicated that dam passage poses a bigger problem to fall chinook at Ice Harbor and Lower Granite dams than at Lower Monumental and Little Goose dams. During the 1991 study, fish remained longer before passing at Ice Harbor and Lower Granite Dam (11.8 and 13.7 days) than before passing Lower Monumental or Little Goose dams (2.2 and 3.1 days), but the extra delay below Lower Granite Dam was not apparent in 1992 (Mendel et al. 1993). Such differential passage conditions are likely to cause different fallback rates at different dams, thereby affecting conversion rates.

These radio tagging studies have demonstrated clearly that wandering up and down stream is a common behavior among Snake River fall chinook. Among fish tagged as they crossed Ice Harbor Dam, 56.8% were last found in Columbia in 1991 and 49.5% in 1992. In 1992, aerial surveys with radio receivers located many of these fish in the Hanford reach of the Columbia River and 22 in the Yakima River (Mendel et al. 1993).

Some of unaccounted loss of radio tagged fish may have been from detection failures. Once tagged fish were lost from detection, it is still possible that many spawned in areas where they were not located. For example, 59% of 42 tagged salmon that crossed Lower Monumental Dam in 1992 were not detected by fixed-site receivers, but were later detected upstream. Such receiver malfunctions may have happened elsewhere. Most fish were lost from detection when they entered deep water. The radio signal from a tag is not detectable when a fish is greater than 30 ft deep in water (personal communication, G. Mendel, Washington Department of Fisheries, Dayton).

The radio tracking studies provided an opportunity to more directly examine interdam loss of fall chinook. We focused on the tracking data between Lower Monumental Dam and Lower Granite Dam, because the fisheries agencies use counts at these two dams to calculate interdam conversion factors. Mendel et al. (1992) tracked 25 fish over Lower Monumental Dam in 1991, and only three of these fish (12%) were lost from detection in areas where they were unlikely to spawn. If we assume none of these three fish spawned (which could not be determined), then this loss equates to a conversion rate of 0.88, compared with a conversion rate of 0.83 reported by TAC (1993) for this portion of the Snake River in 1991. In 1992, 14 of 43 tagged fish crossing Lower Monumental Dam were eventually lost from detection. This equates to a conversion rate of 67%, compared to 84% reported by TAC (1993) based on dam counts. Thus, the radio tracking studies, while demonstrating a high rate of fallback at Snake River dams, do not demonstrate that conversion rates based on Lower Monumental Dam and Lower Granite Dam counts are biased. However, because the fate of tagged fish that disappeared from radio detection is unknown, these studies also do not confirm that interdam conversion rates reflect actual loss of spawners.

Because the radio tagging studies demonstrated there was a high rate of fallback at Ice Harbor Dam, we examined the effect that different fallback rates would have on the harvest rate estimated by the stock accounting method. The only conditions under which fallback would affect estimates of harvest rate would be if the unmarked segment of the run fell back at a greater rate than the marked segment of the run. TAC uses the age and stock composition of marked fish in the broodstock at Lyons Ferry Hatchery to assign age and stock composition to marked fish counted over Ice Harbor Dam. Once these marks are expanded to account for the unmarked portion of the release group they represent, all remaining unmarked fish that have not been assigned to a stock group are assigned to be wild Snake River chinook. In other words, the number of wild Snake River chinook is estimated by subtracting the expanded hatchery run size from the Ice Harbor count. The majority of the URB run is unmarked natural production from the mid Columbia, and the radio tagging studies have demonstrated that many of the unmarked chinook passing over Ice Harbor Dam eventually fallback and spawn in the Hanford reach of the Columbia. Thus, a small portion of these fish dipping into the Snake River as far as Ice Harbor Dam could possibly account for most of the fallback rate at Ice Harbor Dam. If the unmarked fish counted at Ice Harbor Dam have a greater fallback rate than the marked fish (the majority of marked fish are Lyons Ferry stock), then the wild component of SRB escapement would be overestimated. This overestimate would result in an underestimate of harvest rate. We carried out the calculations for the stock accounting method with the actual return data in 1986-l 991, and determined what the true harvest rate on SRB chinook would have been in the cases of 25%, 50%, and 75% fallback by unmarked fish, over and above the fallback rate for marked fish (Figure 13). In other words, we carried out these calculations as if only unmarked fish were falling back. These hypothetical examples show that a 50% fallback of unmarked fish (wild SRB component overestimated by 50%) would mean that the true harvest rate on SRB chinook would be about equal to that estimated by stock accounting for URB chinook (Figure 13).

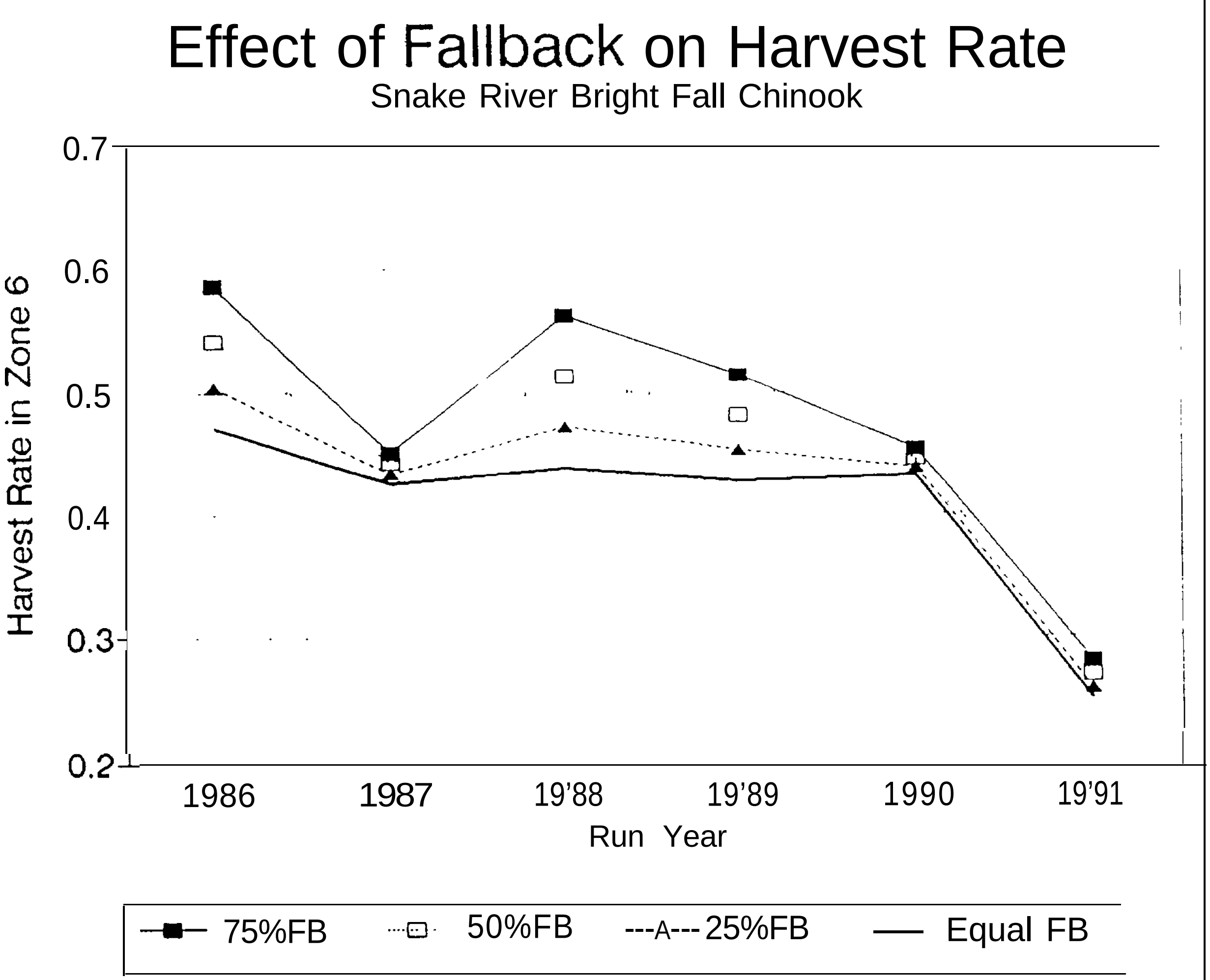

Figure 13. Corrected estimates of harvest rate on ages 4-6 SRB chinook in Zone 6 (stock accounting method) during 1986-1991, given different fallback rates on unmarked chinook.

These fallback rates were treated in the calculations as equal to the overestimate they would have caused of the wild portion of the Snake River population. The line for equal fallback represents the harvest rate calculated from TAC stock and age composition estimates, which makes no adjustment for differential fallback.

Estimation of Conversion Rates Based on Zone 6 Harvest Rate

If we assume that the stock accounting estimate of harvest rate on URB chinook in Zone 6 is the most accurate estimate of harvest rate on fall chinook in that zone (we have deduced that it is), then we can use that harvest rate, along with the number of Lyons Ferry CWT's estimated to have been landed in Zone 6, to estimate the number of Lyons Ferry CWT chinook that crossed Bonneville Dam. Once we know the numbers at Bonneville, we can use the Bonneville to McNary conversion factor and the Zone 6 landings to estimate the number that passed McNary Dam. We did this with age 4 CWT-marked chinook from Lyons Ferry Hatchery, and then applied the conversion factor for McNary to Ice Harbor Dam (from Table 12) to estimate the number of Lyons Ferry CWT's that should have arrived at Ice Harbor Dam (Table 13). We compared these estimates to the number estimated by our cohort method and by the PSC method (Table 13) and found that expansion with the URB harvest rate and the standard conversion factors produced the highest estimate of escapement at Ice Harbor of any of the estimates for the 1989 and 1990 return years and an intermediate estimate for 1988.

This result leads to the conclusion that use of the standard Snake River conversion rates (as we did in the cohort method we used) does not over inflate CWT recoveries at Lyons Ferry Hatchery or at Lower Granite Dam. Alternatively, it could indicate that the estimated number of CWT fish spawning naturally is biased low. Both conclusions may be true. None of the analyses we completed indicated that conversion rates were over estimated.

Catch Expansions

We noted that standard procedures used by TAC for calculating in-river harvest impacts did not include adjustments for mortalities to fish that were contacted by harvest gear, but escaped. PSC (1988) makes such an adjustment for ocean catch. The Klamath River Technical Team (1986) cited evidence that non-landed mortalities from gillnet fishing were equal to 8% of the landed catch. The Klamath Technical Team estimated the 3% of this mortality resulted from pinniped predation on fish tangled in the nets, and 5% of the mortality resulted from net wounds on fish that managed to escape after being entangled in the nets. Rich Turner of Pacific Northwest Utilities

Conference Committee (PNUCC) discovered that conversion rates reported by TAC (1993) were negatively correlated to harvest rates. Similarly, we found the Bonneville to Lower Granite conversion rates were significantly correlated (r= -0.8) with the numbers of fall chinook salmon harvested in Zone 6 during 1986 to 1994 (Figure 14). This relation illustrates that as total salmon harvest

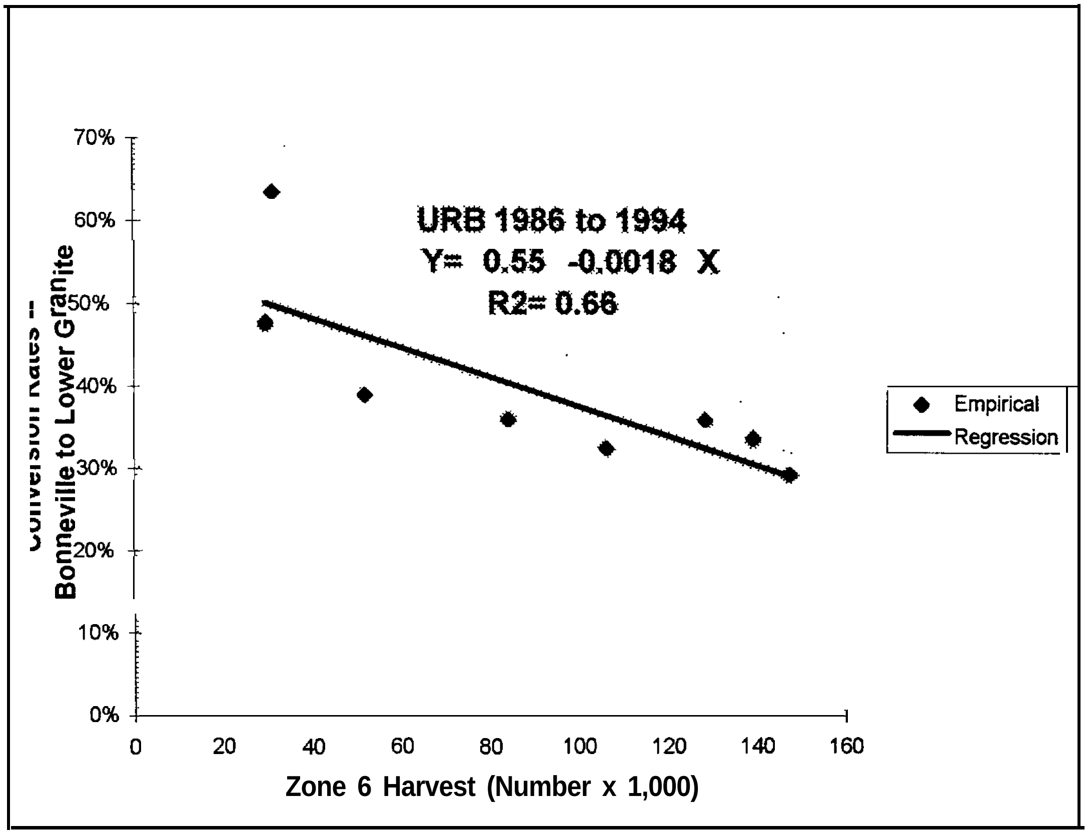

Figure 14. Relation between fall chinook salmon conversion rates (Bonneville to Lower Granite dams) and harvest level in the Zone 6 fishery.

increases, the inter-dam conversion rate decreases. Thus, periods of high harvest are concomitant with high rates of unaccounted losses of adult salmon within the river system. Correlations alone never prove cause-effect, but are important for developing scientific hypotheses, and postulating specific causal mechanisms. In statistical terms, this relationship can be interpreted as 66 percent of the variability in previously unaccounted interdam losses are accounted for by variability in harvest levels. We postulate the following specific mechanisms that could cause increased mortality during periods of liberalized harvest in the ocean and river:

- Incidental mortality of unlanded catch is increased, e.g., increased hook or net injury, and marine mammal predation facilitated by fish restrained in fishing gear
- Latent disease and pre-spawning mortality caused by wounds and stress
- More opportunity (time and area) for illegal catch during liberalized fishing seasons
- High-grading catch, and regulations that cause wastage of sub-legal fish
- Selection of home pack by fishers (via adipose clips or visual identification of specific stocks) to minimize accounting of Columbia River upriver brights

A high incidence of net and hooking wounds has been noted among fall chinook crossing Ice Harbor Dam. Deaths of these fish in the Snake River would reduce the conversion rate. Wounded fish must survive warm temperatures in the Snake River for two months prior to spawning, so a high mortality rate of wounded fish seems likely. We were able to extract data on net and hooking wounds from chinook trapped at Ice Harbor during 1991-I 993 for the radio tagging studies (Table 15). These data indicate that 27% to 37% of the fish passing Ice Harbor Dam have harvest related wounds. It appears likely from this data, when considered in the light of high rates of interdam loss within the Snake River, that harvest impacts extend well beyond the landed catch.

Table 15. Harvest related wounding rates on fall chinook salmon trapped at Ice Harbor Dam. (1991 and 1992 data from personal communication, Rudy Ringe, Idaho Cooperative Fish and Wildlife Unit, Moscow; 1993 data from personal communication Glen Mendel, Washington Department of Fish and Wildlife, Dayton).

Year	Fish Examined	Possible Hooking Wounds		Gillnet Wounds	
		Fish	%	Fish	%
1991	115	11	10%	22	19%
1992	71	10	13%	10	14%
1993	185	37	20%	32	17%

HARVEST SELECTIVITY ON SEGMENTS OF THE RUN

Temporal Selection

We compared weekly catches in Zone 6 to the weekly counts of fall chinook crossing The Dalles Dam during 1988-1990 (Figure 15). This comparison shows that fish were harvested fairly evenly throughout the run in 1989, but that the early half of the run was subjected to less harvest than the later half during 1990 and 1991. A review of the commercial fishing seasons reveals that the selection favoring survival of the early half of the run resulted from a reduction in the number of days open to fishing during the first two weeks of September (Figure 16; Table 16). There were nearly double the number of days open to fishing in early September of 1989 that there were in 1990 or 1991. The historical distribution of fishing days during September-October indicates that selection favoring the early portion of the run is probably a recent phenomenon. The corresponding patterns of harvest effort in Zone 6 and escapement over The Dalles Dam demonstrate that harvest regulations can result in strong selection favoring a portion of the run, so the development of harvest regulations in the future should include measures to preserve the temporal distribution of the run.

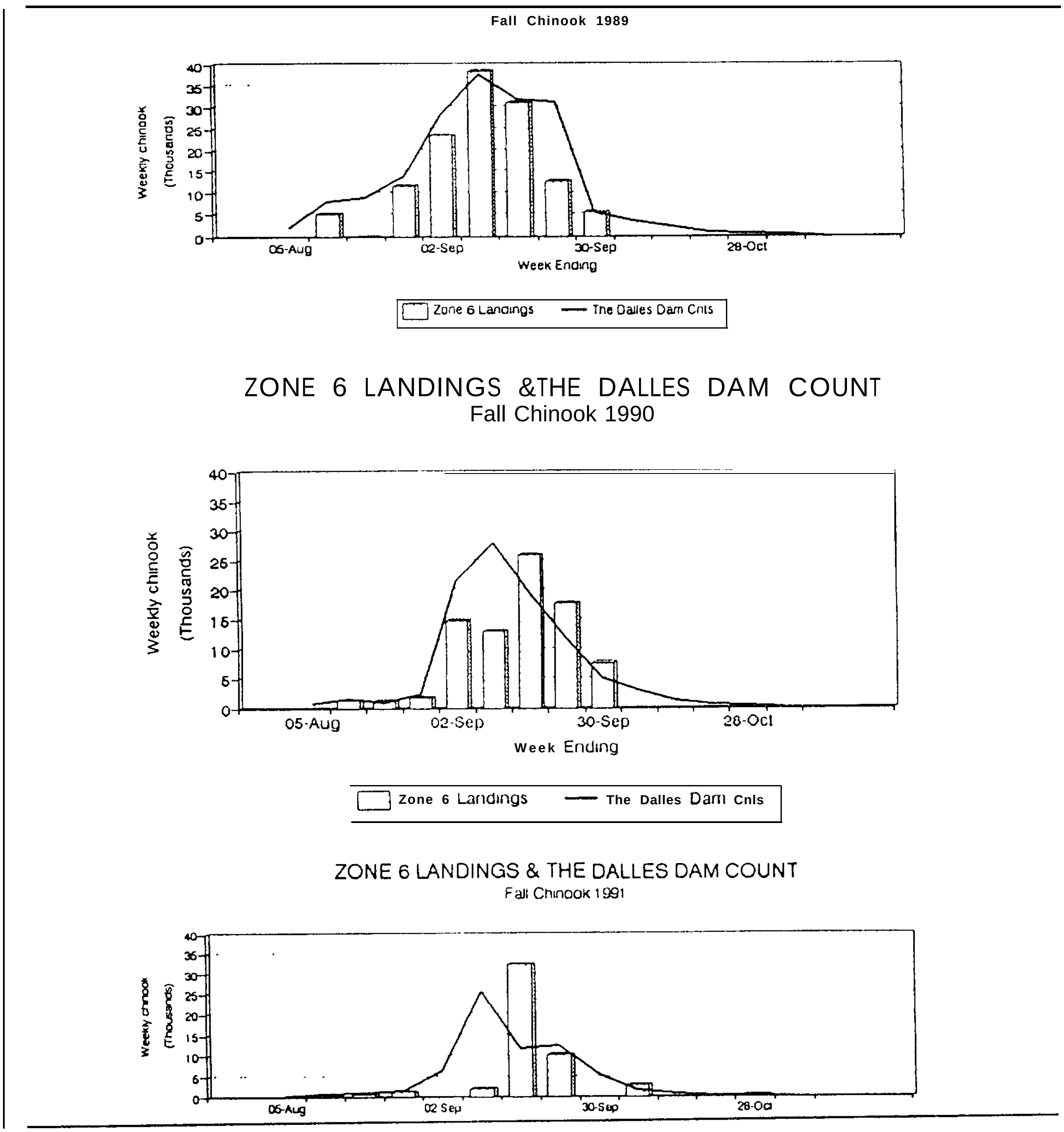

Figure 15. Temporal pattern of fall chinook landings in Zone 6 compared to passage at The Dalles Dam, 1989-1991. (Landing are data from ODFW, Clackamas; dam counts from USACE, Portland).

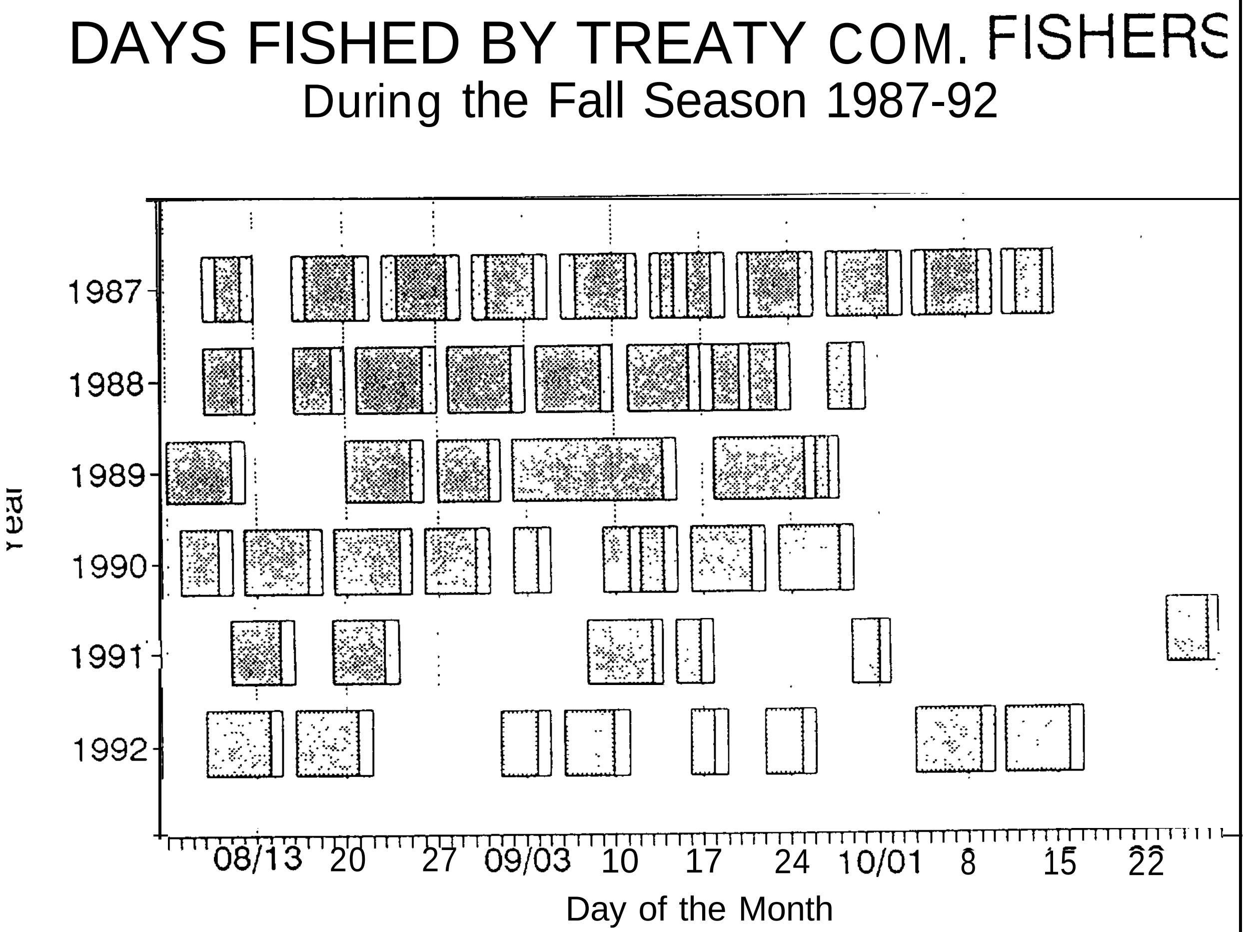

Figure 16. Days open to fishing in Zone 6 (treaty commercial area) during August- October, 1987-1992. (Source: ODFW and WDF 1987-1992). Lightly hatched areas indicate partial days.

Table 16. Number of hours open to gill net fishing in Zones 1 through 5 during 1987-1992. Data are from WDFW and ODFW (1988-l 993).

1987	Hours by Fishing Zone						
Week Ending	1	2	3	4	5	2s	Gear Restriction
13-Aug	36	36					8"min. mesh
20-Aug							
27-Aug							
3-Sep							
10-Sep							
17-Sep	72	72	72	72			None
24-Sep	120	120	120	120			None
1-Oct	120	120	120	120			None
8-Oct	90	90	90	90			None
15-Oct	48	48	48	48			None
22-Oct	72	72	72	72	72	24	None
29-Oct						96	None
5-Nov						96	None
12-Nov						96	None
19-Nov							

1988	Hours by Fishing Zone						
Week Ending	1	2	3	4	5	2s	Gear Restriction
13-Aug							
20-Aug	*11	*18	*18				8"blw LVB; 9"abv LVB
27-Aug							
3-Sep							
10-Sep							
17-Sep	102	102	102	102	78		None
24-Sep	120	120	120	120	120		None
1-Oct	120	120	120	120	120		None
8-Oct	120	120	120	120	120		None
15-Oct	72	72	72	72	72		None
22-Oct	72	72	72	72	72		None
29-Oct	96	96	96	96	120		None
5-Nov	120	120	120	120	120		None
12-Nov	96	96	96	96	120		None
19-Nov							

Table 16. (Continued)

1989 Week Ending	1	2	3	4	5	2s	Gear Restriction
13-Aug	60	60	72	72	72		9"min mesh abv LVBrg
20-Aug		12	12	12	12	12	9"min mesh
27-Aug						72	9"min mesh
3-Sep						12	9"min mesh
10-Sep							
17-Sep	6	6	6	6	6		None
24-Sep	114	114	114	114	114		None
1-Oct	96	96	96	96	96		None
8-Oct	96	96	96	96	96		None
15-Oct	96	96	96	96	96		None
22-Oct	96	96	96	96	96		None
29-Oct	96	96	96	96	96		None
5-Nov	96	96	96	96	96		None
12-Nov	102	102	102	102	102		None
19-Nov	66	66	66	66	66		None

Hours by Fishing Zone: columns 1–5.

1990 Week Ending	1	2	3	4	5	2s	Gear Restriction
13-Aug						24	9" min mesh
20-Aug						60	9" min mesh
27-Aug						36	9" min mesh
3-Sep							
10-Sep							
17-Sep							
24-Sep	78	54	30	30	30	102	" in 2s
1-Oct	96	96	96	96	96		8" in 2s
8-Oct	96	96	96	96	96		8" in 2s
15-Oct	48	48	48	96	96		9" max abv l 205
22-Oct	96	96	96	96	96		9" max abv l 205
29-Oct	48	48	48	48	48	48	9"max - 2s
5-Nov	42	42	42	42	42		9"max - 2s
12-Nov							
19-Nov							

Hours by Fishing Zone: columns 1–5.

Table 16. (Continued)

1991	Hours by Fishing Zone						
Week Ending	1	2	3	4	5	2s	Gear Restriction
13-Aug							
20-Aug							
27-Aug				*36	36		9" min mesh
3-Sep				*24	24		9" min mesh
10-Sep							
17-Sep							
24-Sep	54	54	54	54	30		None
1-Oct	96	96	96	96	96		None
8-Oct	96	96	96	96	96		None, except 9" max in 2s
15-Oct	120	120	120	120	120		9" max - 2s
22-Oct	120	120	120	120	120		9" max - 2s
29-Oct	120	120	120	120	120		9"max - 2s
5-Nov	114	114	114	114	114		9"max - 2s
12-Nov							
19-Nov							

1992	Hours by Fishing Zone						
Week Ending	1	2	3	4	5	2s	Gear Restriction
13-Aug							
20-Aug							
27-Aug							
3-Sep							
10-Sep	12						None
17-Sep							
24-Sep	54	54	54	54	54		8" abv I-5
1-Oct	96	96	96	114	114		8-9.25"abv I-5
8-Oct	72	72	72	72	72		None
15-Oct	48	48	48	48	48		7" max.
22-Oct	102	102	102	102	102		7" max.
29-Oct	120	120	120	120	120		7" max.
5-Nov	18	18	18	18	18		7" max.
12-Nov							
19-Nov							

Evidence of Recent Size Selectivity

Comparison of the length frequency of CWT marked chinook landed in river fisheries with those returning to Lyons Ferry Hatchery makes it possible to evaluate size selectivity of in-river fisheries in recent years. We already presented data on length frequencies of age 3 males and females which indicated there was a size threshold near 70 mm below which chinook had low vulnerability to the gill net fishery (see Figure 5). Length frequencies of Lyons Ferry chinook captured at age 4 further indicate that there may actually be a size optimum for vulnerability to gill net harvest, and that larger and smaller chinook are less vulnerable to harvest. For example, Figure 17 shows that median size of age 4 chinook of the 1986 brood (1990 catch year) in the gill net catch was 850 mm for females and 900 mm for males, compared to 900 mm for females and 950-I 000 mm for males in the hatchery. For each of the brood years we examined, the length frequency of age 4 fish in the gill net catch peaked sharply at 850 mm, while the length frequency of fish returning to the hatchery was more broadly distributed and peaked at the next length interval higher. It is possible that the larger size of fish in the hatchery was influenced by snout elongation during maturation. There was insufficient recoveries of age 5 fish to make similar comparisons. The length frequency comparisons for age 3 and age 4 fish indicate that the greatest selection is against large age 3 fish.

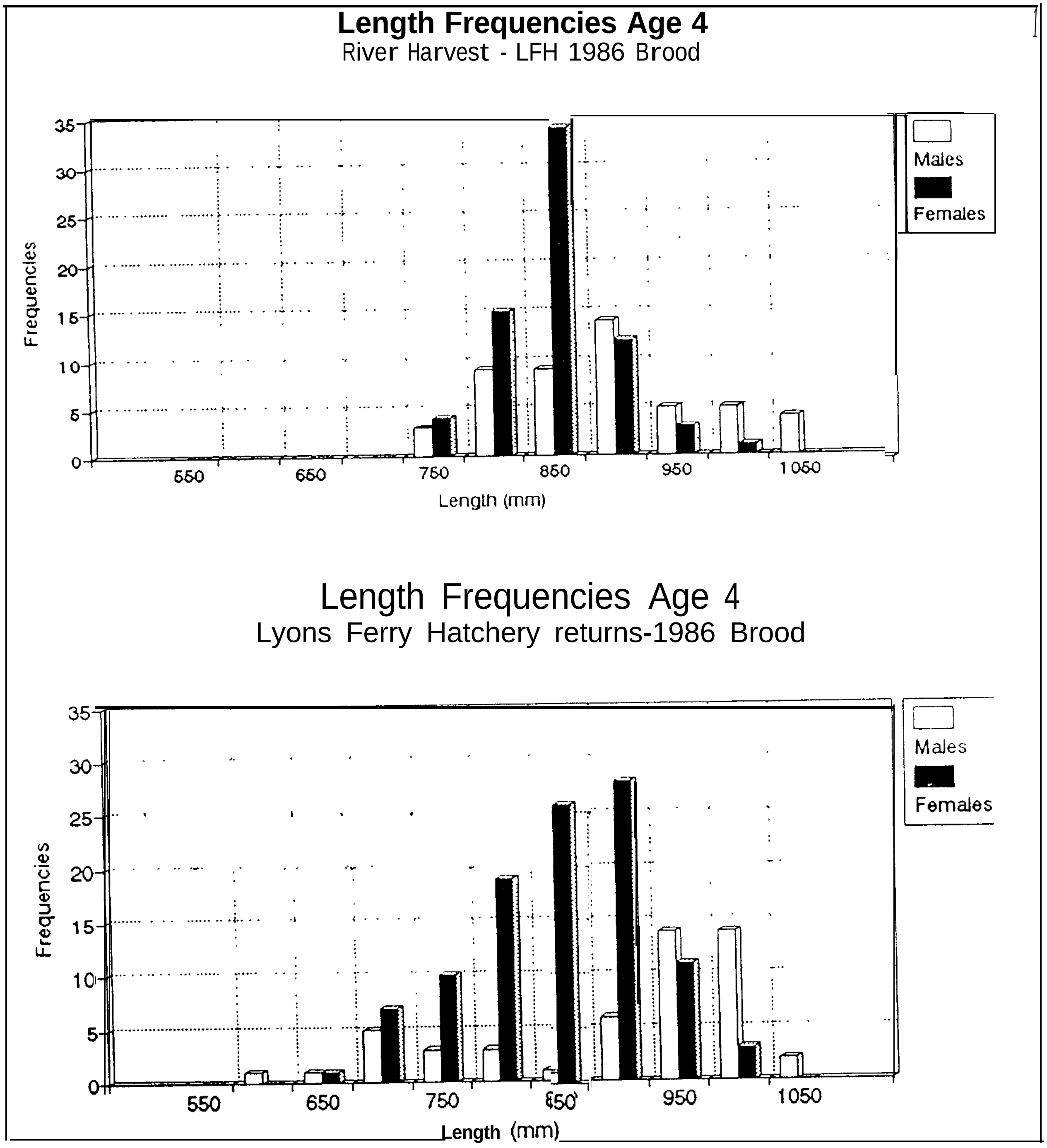

Figure 17. Length frequency of age 4 CWT fall chinook from Lyons Ferry Hatchery that were recovered in the Zone 6 fishery compared to those recovered at the hatchery. Only groups released as subyearlings were used. Data are from PSMFC database.

STOCK COMPOSITION OF THE HARVEST

TAC reports the mix of stock in the fall season commercial fishery each year, based on the expansion of CWT's sampled in the catch. Stocks in the fall chinook catch that are reported by TAC are Lower River Hatchery (LRH), Lower River Wild (LRW), Bonneville Pool Hatchery (BPH), Upriver Bright (URB), and Mid-Columbia Bright (MCB). Landings are typically dominated by URB chinook, but BPH chinook have contributed a high portion of the catch in the most recent years (Figure 18). Within the URB run component, the number of chinook destined for the Snake River is quite small compared to the number estimated to spawn naturally in the Hanford reach of the mid Columbia River (Figure 19). We present the data in Table 17 as an example of the CWT recoveries that can be used to estimate stock composition of the Zone 6 catch.

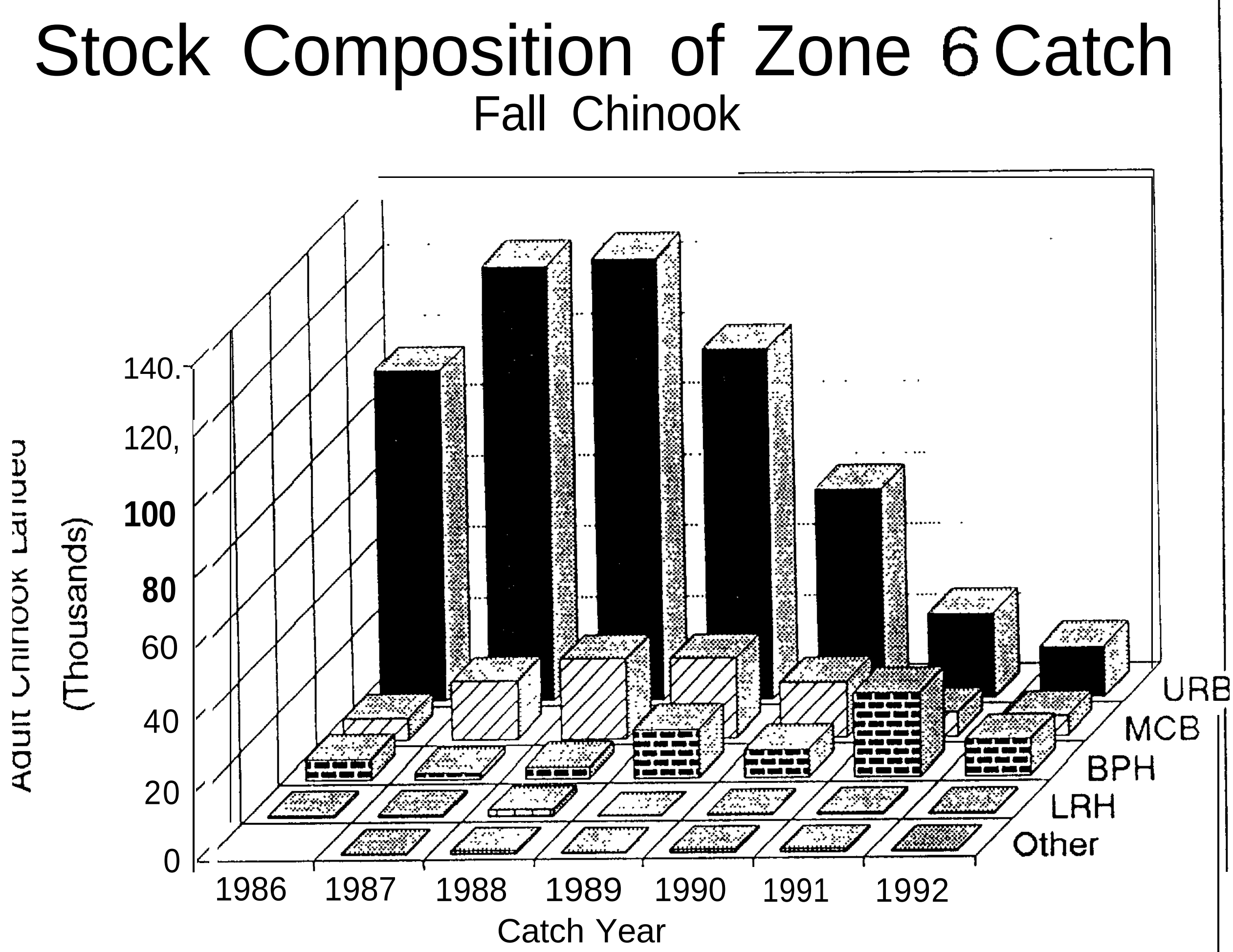

Figure 18. Stock composition of the fall chinook landings in Zone 6,1986-1992. Data are from TAC (19864992).

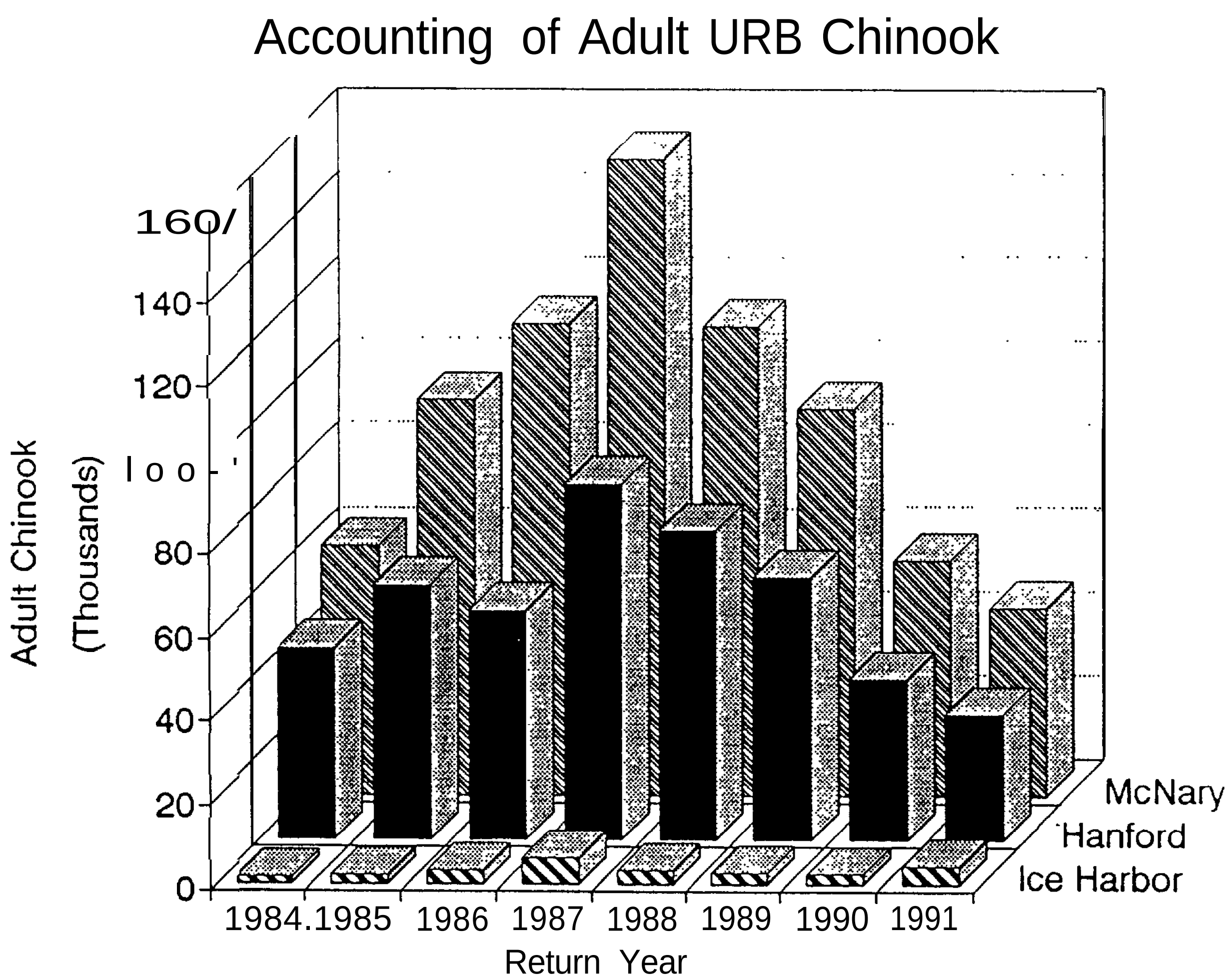

Figure 19. Number of URB chinook estimated to pass McNary Dam, spawn in the Hanford reach, and pass Ice Harbor Dam each year, 1984-1991. Data are from TAC (1984-1992).

Table 17. CWT's recovered in the Zone 6 fishery during 1990. Data are from PSMFC database.

Tagcode	Tagged	Untagged1	Hatchery Name	Brood Year	86	87	88	89	90	91	92	TT'
632152	250831	236894	LFH[2]	83	354	1738	414	11				2517
633218	83611	78964	LFH	83	68	598	170	15				851
632841	258355	183321	LFH	84		16	91	133	10			250
633226	78417	101400	LFH	84	3	43	53	19				118
633227	78064	100900	LFH	84	2	34	66	10				112
633228	78504	101400	LFH	84	6	17	39	6				68
633633	49112	366	LFH	85			4	9	7			20
633634	49112	366	LFH	85			8	10	3			21
633635	49112	366	LFH	85				8				8
633636	49113	367	LFH	85				10	8			18
633637	49112	366	LFH	85			3	10				13
633638	98650	468	LFH	85				18				18
633639	49325	468	LFH	85			4	15	3			22
633640	49325	468	LFH	85			3	29	4			36
633641	49325	468	LFH	85				15				15
633642	49325	468	LFH	85		4		16	2			22
634156	152479	1075	LFH	85			31	314	75			420
634159	156036	470	LFH	85			47	389	117	2		555
634261	125570	2824	LFH	86			4	19	32			55
634262	127715	1030	LFH	86			7	33	44	7		91
634401	128283	1034	LFH	86			19	51	40	13		123
634407	60523		LFH	86					35	7		42
634408	60281		LFH	86				8	41	11	2	62
634411	58735		LFH	86				3	41	7		51
634413	58970		LFH	86				14	26	5		45
634750	59608		LFH	87					16	32	13	61
634752	57756		LFH	87					6	5	3	14
634755	59609		LFH	87						19	15	34
634756	57594		LFH	87					4	2	2	8
635214	124345	839682	LFH	87					3	2		5
635216	124394	840018	LFH	87						5		5

[1] TT= total number of fish tagged
[2] LFH= LYONS FERRY HATCHERY

Table 17. (Continued)

Tagcode	Tagged	Untagged	Hatchery Name	Brood Year	86	87	88	89	90	91	92	TT
630226	113193	18244	LFH	88							2	2
630231	58988		LFH	88						2	39	41
630232	58989		LFH	88						6	36	42
630235	55922		LFH	88						3	11	14
630237	56597		LFH	88							32	32
635549	118104		LFH	89							4	4
632848	74170	575313	PRC[3]	83	107	222	51	3				383
632859	74392	577039	PRC	83	109	148	40	3				300
632860	74170	575313	PRC	83	58	169	61					288
632330	107461	85671	PRC	84		21	156	136	4			317
633221	103665	606236	PRC	84	3	86	311	104				504
633222	105224	606237	PRC	84	42	161	360	83	3			649
634102	203534	2749176	PRC	85			37	168	54			259
051915	48975	149281	PRC	86				3	29	10	3	45
051916	49769	151703	PRC	86				20	22	6		48
051917	49331	150323	PRC	86					18	6		24
051918	48796	148692	PRC	86				16	18	6		40
051919	49551		PRC	86				6	6			12
051920	48943		PRC	86				5	3			8
051921	49511		PRC	86					9	2		11
051922	48995		PRC	86				6	2			8
634128	201779	4742183	PRC	86				25	49	11		85
635226	196221	7297574	PRC	87						4	3	7
635249	201608	4997537	PRC	88						5	2	7
630732	194530	6024260	PRC	89						3	16	19
634057	199469	4838160	PRC	90							2	2
632857	197528	56272	TRP[4]	83	185	933	299	24				1441
632858	202861	49407	TRP	84		4	54	226	26			310
633112	208492	28975	TRP	85			95	550	241	42		928
632843	227964		TRP	86				14	3			17
634952	175069		TRP	87				3		12	15	30
635907	90306		TRP	89							28	28
634223	90100		TRP	90							3	3

[3] PRC= PRIEST RAPIDS CHANNEL

[4] TRP= TURTLE ROCK POND

SIMULATION OF ALTERNATIVE IN-RIVER HARVEST REGULATIONS

We utilized the CRiSP.2 harvest model developed by Dr. James Norris, University of Washington, to simulate the effects of alternative harvest management regulations on spawning escapement of Snake River fall chinook salmon. We worked with Dr. Norris to develop model scenarios and input parameters; and he conducted the model runs and helped interpret the results. These analyses help elucidate three important types of information: (1) the sensitivity of model results to key input parameters; (2) critical assumptions and uncertainties, and (3) comparisons of the potential of different management options to allow for rebuilding and recovery of the Snake River populations. The Lyons Ferry Hatchery population is the surrogate stock used to represent wild Snake River fall chinook salmon since it represents the original genetic race, and it is the only component of the "ESA species" that has a CWT data base to collect recovery information to determine harvest rates and stock-recruitment. Only recoveries from subyearling hatchery releases are used to represent the wild stock since they represent the life history pattern of naturally spawning Snake River fall chinook salmon.

HARVEST MODEL DESCRIPTION

CRiSP.2 is a computer model that simulates the harvest of 30 chinook salmon stocks by 25 fisheries, and projects population dynamics -- including future run sizes and spawning escapements (Norris 1996). The computational engine of CRiSP.2 is based on the forecasting portion of Pacific Salmon Commission 'Chinook Model" (PSC 1993). A key feature of the model is the interaction between stocks through annual catch ceilings, or quotas, imposed upon fisheries that harvest multiple stocks. As the 30 different salmon, populations increase or decrease at different rates over time, relative harvest rates in fisheries with catch ceilings also change (Norris 1996). Since catch ceilings are the primary management tool of PSC ocean fisheries, a multiple stock model that incorporates this type of interaction is required for realistic simulations. The CRiSP model also has the flexibility to evaluate in-river harvest management options including fixed escapement goals, stock/fishery specific harvest rate strategies (e.g., time/area closures), size limits, inter-dam losses during adult migrations, and enhancement activities.

CRiSP.2 is an accounting device for tracking the fate of individual chinook salmon cohorts through time. Most model parameters -- e.g., cohort sizes, age specific harvest rates, maturity schedules, incidental mortalities -- are estimated by the PSC Chinook Technical Committee based on CWT recoveries and cohort analyses. The annual computational cycle includes the following steps (Norris 1996):

- Population aging at the start of each year, maximum is 5 years.
- Natural ocean survival assumed to be: 0.5, 0.6, 0.7, 0.8, and 0.9 for ages one through five, respectively.
- Preterminal (ocean) fishing mortality, including legal catches and incidental mortalities, e.g., shakers or sub-size releases (does not include unaccounted illegal take).
- Sexual maturation are stock and age specific; some stocks with variable rates.
- Terminal (river) fishing mortality (does not include incidental mortalities and illegal take).
- Pre-spawning mortality and inter-dam losses
- Production of progeny in the next year based on stock-recruit functions and assumed brood year survivals {**Environmental Variability** (EV) scalars}.

At this time, CRiSP.2 does not have calibration capability, and therefore, calibrated parameters must come from the PSC Chinook Technical Committee. The PSC Chinook Model is calibrated by finding a suite of stock and year-specific brood year survival rates that results in model outputs that closely match user specified terminal run sizes, escapements, or catches for individual stocks during the base period. The model results are sensitive to the selection of the EV scalars for the simulation period (Norris 1996).

The model can be run in either stochastic (Monte Carlo) or deterministic (scenario) mode. Stochastic mode tracks cohorts through many time series, each with a different set of key parameters. We conducted analyses in the deterministic mode which tracks the cohort through a single time series and a single set of assumptions. We made assumptions about the mean values of key parameters such as brood year survival rates (EV scalar) and maturation schedules. For the simulations in this report, the base period was 1979 to 1995 and the simulation period was 1996 to 2017.

SENSITIVITY ANALYSIS OF ENVIRONMENTAL VARIABILITY (EV) SCALARS

A major assumption of the PSC and CRiSP models is pre-recruitment brood year survival rates that are estimated using "**Environmental Variability**" (EV) scalars. The stock-specific EV value is considered a pre-recruitment (i.e., prior to age one) survival scalar that actually adjusts for the combined effects of <u>two</u> factors: (1) environmental variation that affects survival in a given year, and (2) bias in production function parameters. EV scalars are used to calibrate PSC model, for each stock, to match empirical annual adult returns. In the model, the number of age 1 fish produced each year is calculated according to the following equation:

Equation 10: Age? Fish= EV * Stock-Recruit Estimate

A stock-specific arithmetic mean EV scalar value -- based on the historical period of record, e.g., 1979-l 992 -- is used in the PSC Chinook Model for projections of future population dynamics. Measures of central tendency for EV scalars of the 30 chinook stocks from the PSC technical committee calibration number 9525 indicate substantial variability among stocks (Table 18). In all cases the arithmetic mean value is greater than the geometric mean. The geometric mean is the appropriate statistic to use when, as for the EV scalar data, frequency distributions of the values are highly skewed -- indicative of a negative binomial distribution (J. Norris, UW, June 28, 1995, Personal Communication). Therefore, if the geometric mean is the statistically valid measure for baseline conditions, the productivity of all the 30 chinook stocks is overestimated in PSC simulations of future run sizes -- by using the arithmetic mean.

Table 18. Three measures of central tendency of EV scalars of the 30 chinook stocks from the PSC technical committee calibration number 9525 (J. Norris, UW, June 28, 1995, Personal Communication).

Stock Number	Number of years (n)	Arithmetic Mean	Median	Geometric Mean (m)
[illegible]	13	0.8698	0.5838	0.5303
2	13	0.9399	0.9186	0.8949
3	13	1.1516	1.0893	1.0787
4	14	1.1144	1.1953	0.8909
5	14	1.0326	1.0658	0.6358
6	14	1.0326	1.0658	0.6358
7	12	1.0470	0.9267	0.8129
8	13	0.4208	0.3388	0.3735
9	13	0.9111	0.4670	0.5810
10	14	1.4438	1.2071	1.2481
11	14	0.4041	0.4060	0.3614
12	14	0.9282	0.7463	0.8369
13	14	0.4041	0.4060	0.3614
14	5	0.4252	0.5108	0.2832
15	13	0.5840	0.4825	0.5012
16	12	1.0187	0.8135	0.8534
17	14	0.4668	0.4586	0.4229
18	13	1.2015	0.8861	1.0372
19	14	2.9020	2.5370	2.4545
20	14	0.2882	0.2310	0.2200
21	14	0.4406	0.2930	0.3293
22	14	0.4406	0.2930	0.3293
23	14	0.3107	0.2714	0.2573
24	14	0.2124	0.2253	0.1926
25	14	0.3128	0.3066	0.2600
26	14	0.5824	0.5638	0.4540
27	14	0.9860	0.8339	0.6028
28	13	1.1159	0.8801	0.6908
29 (SRB)	13	5.8761	4.7091	4.7433
30	14	1.0551	0.2987	0.4982

A frequency distribution of the combined EV scalars 28 chinook stocks compared to the values for SRB's and URB's is presented in Figure 20. It is clearly apparent that the EV scalar values for the Columbia River upriver bright stocks (URB and SRB) have much different distributions and mean values compared to the EV scalars for the other 28 chinook stocks in the PSC data base. For example, 95% of EV scalar values of the 28 other stocks are less than 2.0 and only 0.5% are greater than 4.0. In contrast, 21.4% of EV scalars for URB's and 69.2% of EV scalars for SRB are greater than 4.0. By definition, the exceptionally high EV scalar values for SRB's could be attributed to two factors: (1) greater environmental variability in the Snake River system and higher overall productivity due to "boom" years, or (2) uncertainty in the stock-recruitment function that results in unreliable estimates of annual age 1 production based on spawner abundance. Since the Snake River stock has been declining drastically since the mid-1970's it is unlikely that the stock is now more productive as a result of environmental variability. It is much more likely that the stock-recruit function is unreliable, especially since the one utilized in modeling was derived from data on the mid-Columbia stock (Schaller and Cooney 1992). Recent research indicates that the data base for Snake River fall chinook salmon is inadequate to develop a valid stock-recruit functional relationship (Lorraine Reed, University of Washington, MS 1996).

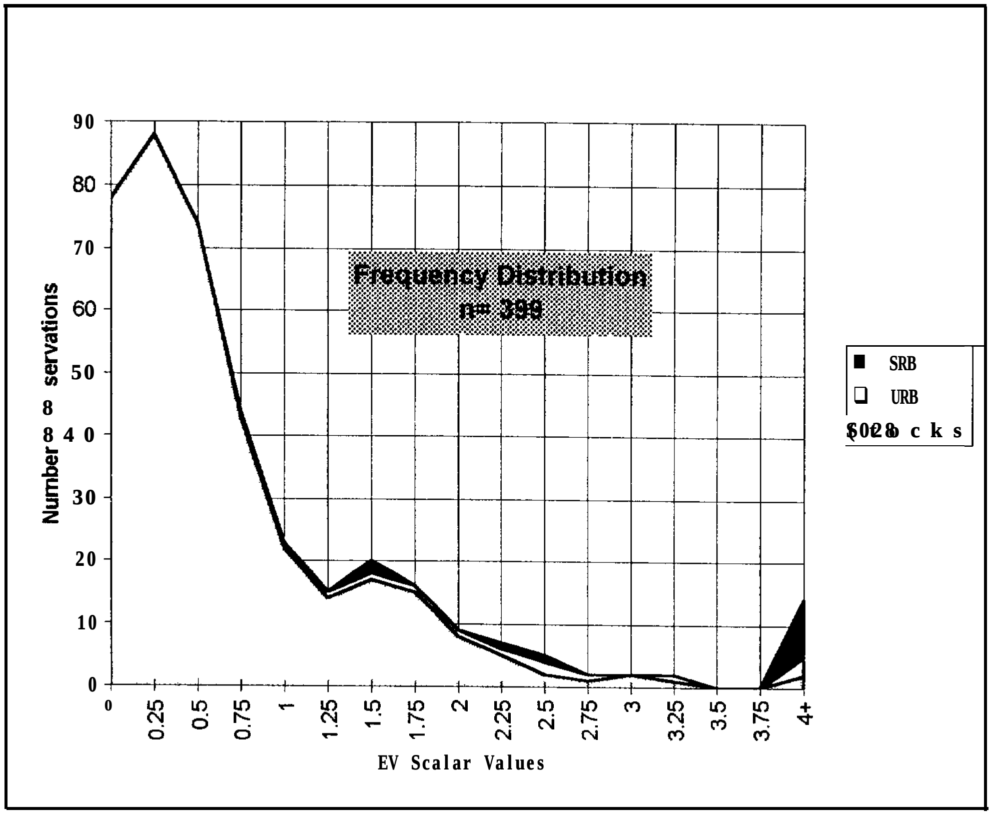

Figure 20. Frequency distribution of EV scalars for 30 salmon stocks used in the Pacific Salmon Commission "Chinook Model" calibration (Source Jim Norris, UW, 1995).

We conducted a series of CRiSP.2 simulations to test the sensitivity of model results to the assumed geometric mean baseline EV scalar values used for future projections during years 1996 to 2017 (Figure 21). In these simulations, all other parameters were held at constant levels representing status quo baseline conditions. At EV scalar values of 4.0 and greater, the Snake River fall chinook escapement increased rapidly to levels above 5,000 spawners. For example at EV= 4.8 (mean of PSC baseline), the population increased as follows:

1 generation > 1,000
2 generations > 2,500
3 generations > 4,500
4 generations = 6,000

Assuming an EV of 3.0, the population would increase gradually to 1,000 spawners. At an EV of 2.0 the SRB stock would decrease to less than 100 spawners after five full generations. Extinction would be the outcome of simulations with an EV scalar of 1 .O.

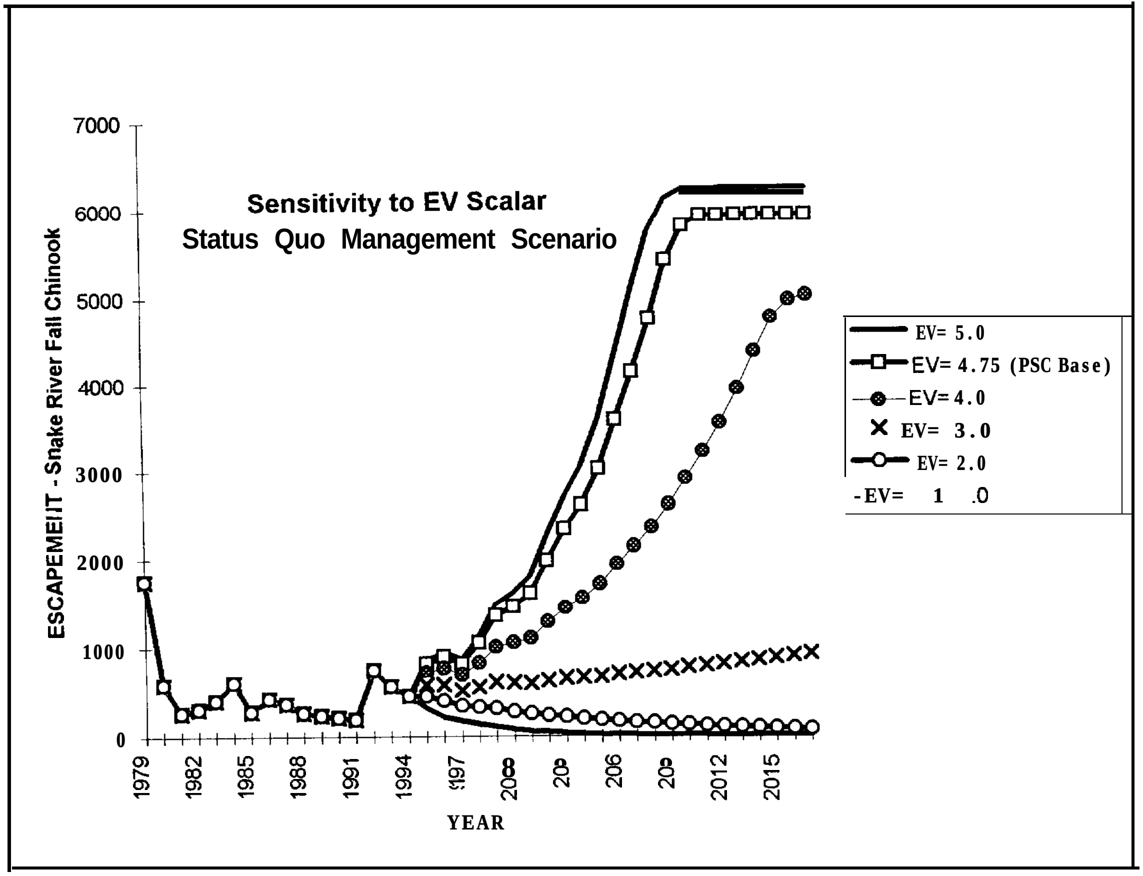

Figure 21. Sensitivity of simulations of Snake River fall chinook salmon escapement projections to various EV scalar values, ranging from 1 .O to 5.0 (Source Jim Norris, UW, 1995).

The sensitivity analysis indicates that the production function and assumed annual EV scalar values are critical uncertainties of the PSC and CRiSP.2 harvest models. If one assumes the mean EV scalar value of the PSC 1979-92 data base is representative of the SRB stock for future deterministic projections, then the ESA-listed species would appear to be healthy and robust under status quo management conditions. That conclusion is clearly not valid given the progressive decline of the Snake River fall chinook stock over the past 20 years.

We examined empirical data of Lyons Ferry Hatchery fall chinook returns to achieve a more valid picture of population trajectory to use for modeling future projections. The data indicate that both adult and jack returns are characterized by decreasing trends (Figure 22). The adult return in 1994 was 1,284 adults and 157 jacks. The record low

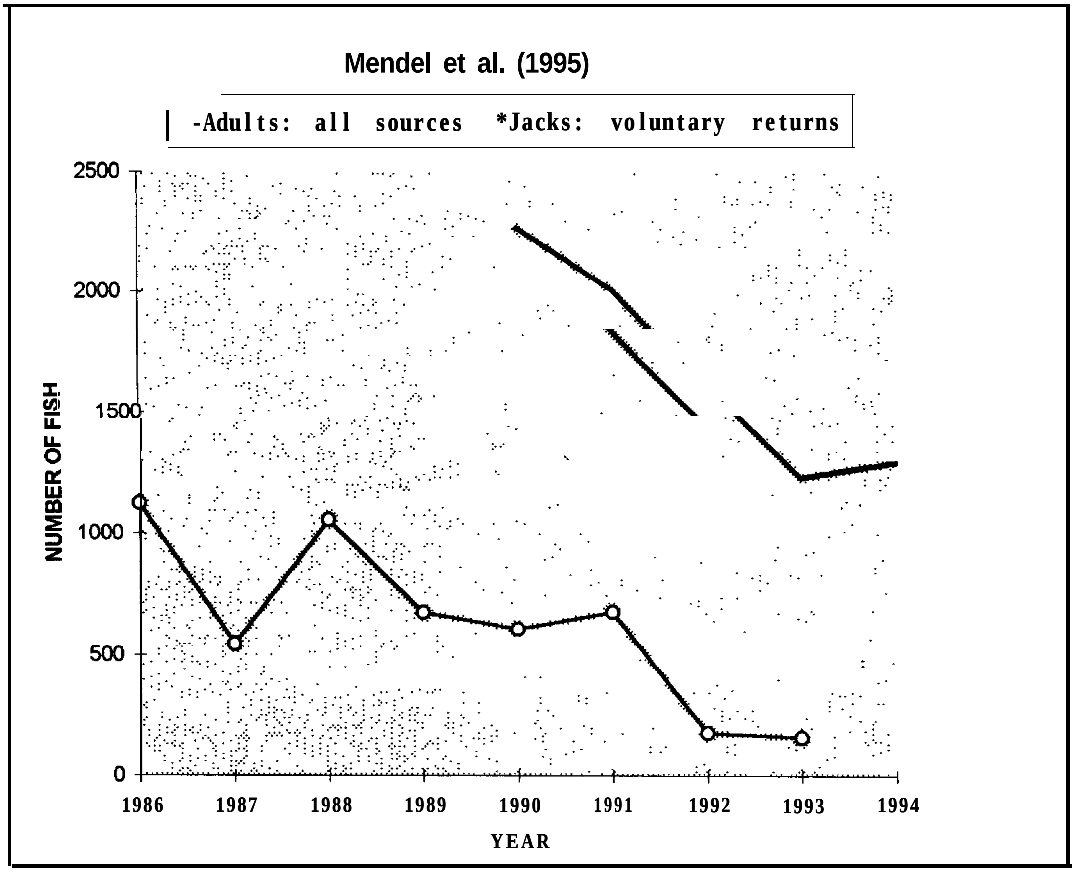

Figure 22. Returns of Snake River fall chinook salmon (adults and jacks) to the Lyons Ferry Hatchery, 1986-l 994 (Source: Mendel et al. 1995).

return of jacks during 1992-l 993 is particularly alarming since jack run size is an empirical predictor of future adult run size. Given the empirical trends in the population trajectory of the indicator stock of Snake River fall chinook compared to the results of the sensitivity analysis -- an EV scalar of 2.0 is our best approximation of a realistic value for the following CRiSP.2 simulations.

SIMULATION OF POPULATION RECOVERY UNDER ALTERNATIVE HARVEST SCENARIOS

We analyzed three types of alternative harvest management strategies: (1) fixed escapement policy at McNary Dam, fixed harvest rate of SRB's, and selective harvest effectiveness.

SIMULATION OF EFFECTS OF FIXED ESCAPEMENT POLICY -- 45,000 AT McNARY DAM

Currently, in-river harvest of upriver bright fall chinook salmon is managed with a fixed escapement policy of 45,000 adult salmon at McNary Dam. Harvest is presently not managed to achieve a specified spawning escapement of the ESA-listed Snake River fall chinook stock, e.g., at Lyons Ferry Hatchery and/or Lower Granite Dam. We simulated the long-term impacts of setting harvest levels to achieve a fixed escapement of various levels (45,000 to 125,000) of the aggregate upriver bright fall chinook salmon at McNary Dam -- on escapements of the Snake River fall chinook stock (Figure 23).

The model simulations indicate the 45,000 McNary Dam fixed escapement policy would result in extinction in about three more generations. The stock would continue to decline, although at a slower rate, at target levels of 65,000 to 105,000 fish at McNary. It would take a McNary escapement level of about 125,000 aggregate URB's to ensure a positive population trajectory of the SRB stock. An escapement policy of 125,000 URB's at McNary Dam would eliminate harvest in years of low URB run size. The aggregate URB fall chinook run entering the Columbia River -- that could be expected to reach McNary Dam in the absence of harvest -- has ranged from 73,000 to 127,000 during 1990-I 994, and 236,000 to 373,000 during 1986-89 (Table 19).

Table 19. Estimates of potential run sizes of URB and SRB fall chinook salmon at McNary Dam in the absence of harvest, 1986-1994 (Data on Columbia River run sizes and conversion rates from US v. Oregon TAC 1995).

Year	URB's entering Columbia River	SRB's entering Columbia River	Bonneville to McNary Conversion Rate	Maximum URB's at McNary Dam (no harvest))	Maximum SRB's at McNary Dam (no harvest))	Actual SRB Passage at L. Granite Dam (LFH & wild)
1986	281,551	5,661	0.9930	279,580	5,621	774
1987	420,661	16,067	0.8877	373,421	14,263	897
1988	339,918	7,020	0.9760	331,760	6,852	569
1989	261,093	4,887	0.9040	236,028	4,418	501
1990	153,435	5,076	0.8287	127,152	4,206	252
1991	102,717	6,596	0.7747	79,575	5,110	517
1992	81,014	5,334	0.8999	72,904	4,800	633
1993	102,907	4,369	0.8305	85,464	3,628	785
1994	132,885	2,270	0.8355	111,025	1,897	426

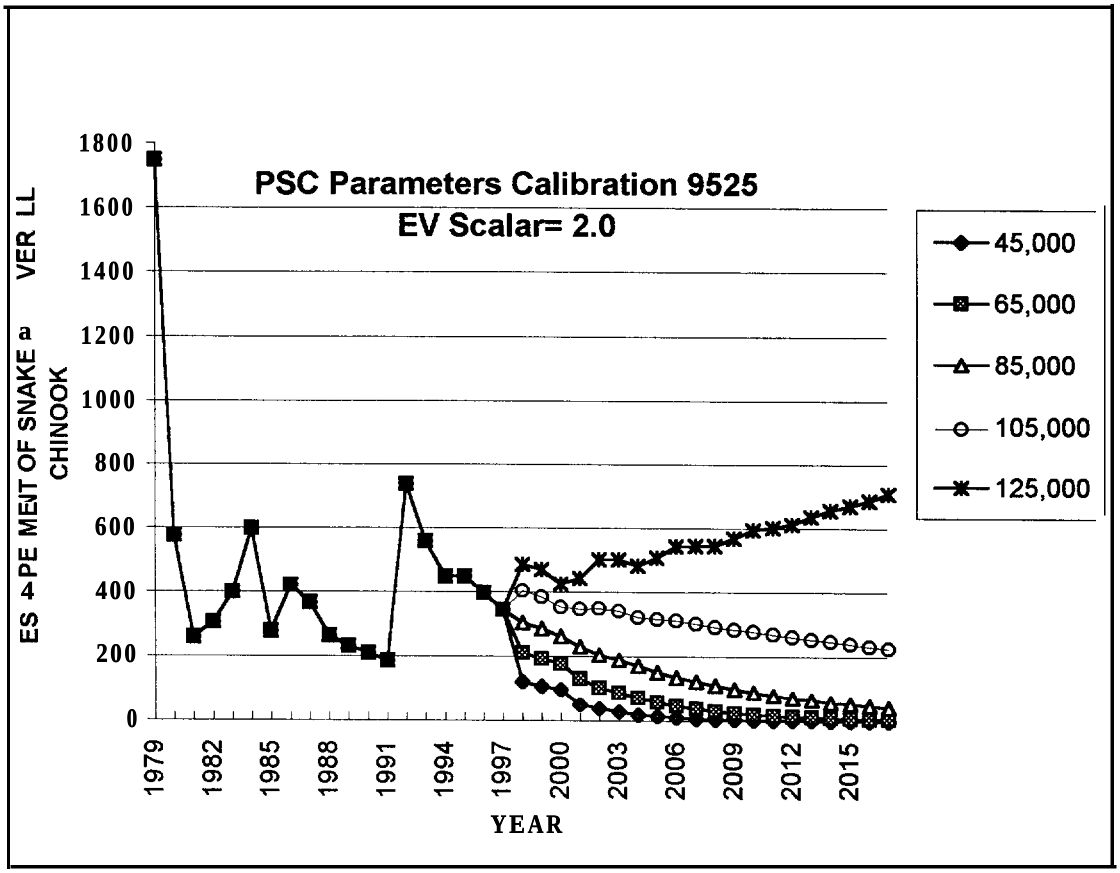

Figure 23. Effects of fixed escapement policy of 45,000 to 125,000 adult fall chinook salmon on simulated escapement of Snake River fall chinook salmon, given an EV scalar of 2.0 (Source Jim Norris, UW, 1995).

SIMULATION OF A FIXED HARVEST RATE ALTERNATIVE

A fixed harvest rate policy would set a combined (Zone 1-6 commercial and sport) harvest rate goal for inriver fisheries. The combined harvest rate was defined to be the fraction of the aggregate (URB+SRB) adult run size entering the river that is taken by all fisheries. The model predicts that harvest rates of 10 to 25% on the aggregate URB stock would result in further declines of Snake River fall chinook salmon. A harvest rate between 510% would stabilize SRB escapement levels. Harvest rates less than 5% would be needed to facilitate SRB stock rebuilding.

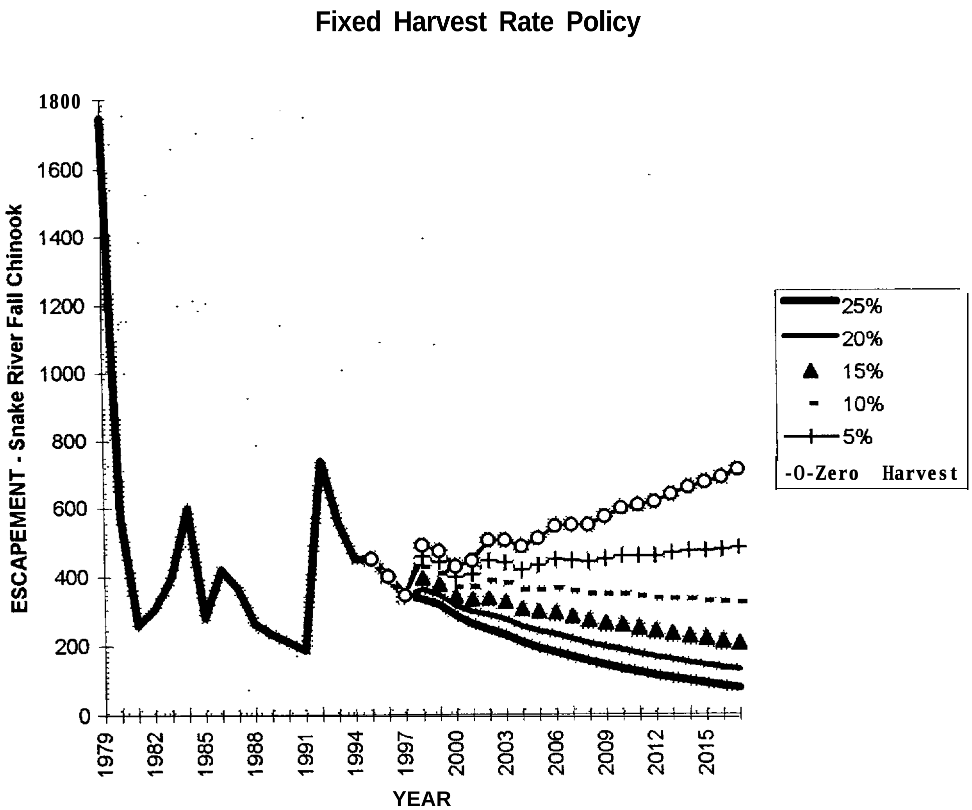

Figure 24. Simulated escapement of Snake River fall chinook salmon under various fixed harvest rate scenarios (Source Jim Norris, UW, 1995).

SIMULATION OF SELECTIVE HARVEST EFFECTIVENESS

The goal of selective harvest of specific strong stocks of upriver bright fall chinook salmon would be to provide commercial, sport, and ceremonial & subsistence (C&S) harvest opportunities, while protecting the ESA-listed Snake River stock from excessive harvest rates. It is likely that live-capfure-and-release selective fisheries on chinook salmon would be more effective for river fisheries than for ocean fisheries (Vigg 1995). Snake River fall chinook are taken incidentally in troll and sport fisheries from Southeast Alaska to California, in non-treaty Columbia River sport and commercial fisheries, and in Zone 6 Treaty fisheries (Table 20; Schmitten et al. 1995). Each fishery taking Snake River fall

Table 20. Distribution of adult coded-wire tag recoveries of Snake River fall chinook salmon tagged as yearlings and subyearlings (from NMFS Proposed Recovery Plan 1995; p V-3-6).

Area	Yearling Recoveries (%)	Subyearling Recoveries (%)	Total Recoveries (%)
Alaska	6	1	2
Canada	42	29	32
Washington Coast	9	16	15
Columbia River Below Bonneville Dam	9	14	13
Columbia River Below Bonneville Dam	25	18	19
Oregon Coast	7	18	16
California	2	3	3
TOTAL	100	100	100

chinook is a mixed stock fishery targeting other strong stocks. Since the tag recoveries were distributed over all time periods and management areas within each management jurisdiction -- there is no apparent opportunity to shift ocean fisheries in time and space to reduce the incidental harvest of Snake River fall chinook while targeting healthy stocks (Schmitten et al. 1995). Similarly, PSC (1995) concluded that selective fisheries for chinook salmon in the ocean should not be considered because of the logistics of marking, the complex life history pattern, and the difficulties of coordination of coast-wide fisheries (across jurisdictions). The proposed NMFS Recovery Plan (Schmitten et al. 1995), however, supported the proposal to study the effects of ocean and Columbia River fisheries -- that presently selectively catch large females -- on the productivity and rebuilding potential of Snake River fall chinook salmon. Another method to implement selective river fisheries would be to harvest only in terminal areas, tributaries, and in the mainstem Columbia River above the confluence of the Snake River. Although logistically and technologically simple, the latter approach would have difficult social, cultural and institutional constraints.

Since the prohibition or elimination of the highly efficient live capture gear types in the Columbia River during 1925 to 1950, gill nets have become the primary method for the commercial harvest of salmon. Time, area, and gear (e.g., net size and mesh size) restrictions have been used to regulate total catch and target different temporal segments of runs, different sizes and species of salmon, and different stocks within species (Vigg 1995). Gill nets are not suitable for selective fisheries that require live release because gillnet mortality rates are very high. PSC (1995) summarized release mortality rates as follows: (a) recreational gear, traps, reef nets, beach seines, and fish wheels have the lowest mortality rates, (b) commercial troll and purse seine (low catch/haul) fisheries have intermediate mortality rates, and (c) gillnet and purse seine (high catch/haul) fisheries have the highest release mortality rates.

It is beyond the scope of this report to examine the feasibility of different methods and approaches (e.g., gear, time, area, fish size/sex) to implement selective fisheries. A proposal to look at the feasibility of selective harvest of chinook salmon in the Columbia River is outlined in detail by Vigg (1995). Our approach in this report is simply to examine various levels of effectiveness in reducing harvest levels on SRB's while allowing selective river harvest of other stocks of URB's, e.g., the stronger mid-Columbia stock. Selective fisheries would have to be at least 70% effective in reducing SRB harvest rates in order stabilize the simulated future Snake River fall chinook population trajectory at about 450 spawners (Figure 25). Selective fisheries would have to be 90-100% effective (i.e., SRB harvest <10% of URB baseline harvest rates) --- in order to facilitate rebuilding and recovery of Snake River fall chinook salmon.

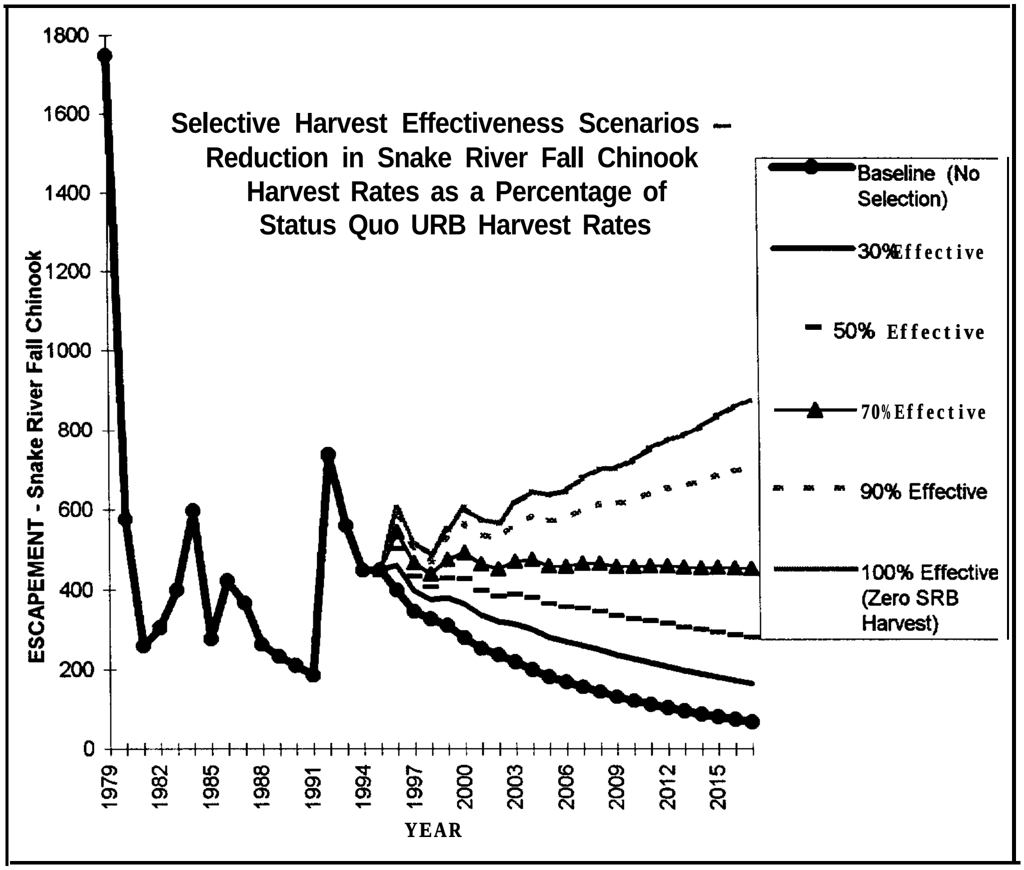

Figure 25. Simulation of Snake River fall chinook salmon escapement under various levels of selective harvest effectiveness – expressed as a percentage reduction of baseline URB harvest levels (Source Jim Norris, UW, 1995).

CONCLUSIONS

Harvest rates on URB fall chinook were dangerously high through 1990, even for a healthy stock that did not face substantial passage mortality. Only in times of high ocean productivity are chinook likely to be capable of sustaining such high harvest rates. The URB fall chinook in the Deschutes River, which pass only two dams and appeared quite healthy in many years, have been declining in recent years. In-river harvest rates decreased substantially since the Snake River fall chinook stock was listed as threatened or endangered under the ESA. Model simulations indicate that harvest rates on SRB's will have to continue to be reduced over baseline URB levels in order to facilitate population rebuilding. The combined effect of various factors, discussed below, cause an underestimate of harvest impacts on SRB's.

FACTORS THAT UNDERESTIMATE HARVEST IMPACTS ON SNAKE RIVER FALL CHINOOK SALMON

Several factors have biased previous evaluations of the potential impacts of status quo harvest management on Snake River fall chinook salmon. All of the following factors cause underestimates of actual impacts on the stocks potential to rebuild and recover.

Bias #1. Including age 3 fish in calculations of average harvest rates:

- Most age 3 fish are males, and significantly smaller size;
- Age 3 fish are not as vulnerable to gill nets, and have lower harvest rates;
- Most female chinook mature at ages 4-6;
- Escapement of <u>females</u> is most important to stock productivity;
- Including age 3 makes average harvest rate 1 O-l 5% less than actual for age 4.

Bias #2. Assuming that SRB harvest rates average only 84% of URB harvest:

- Timing of catch of SRB's and URB's is nearly identical (Figure 1);
- SRB run size is less than 2% of URB run size; small sample size may bias CWT expansions and population estimates;
- Stock accountability methods assume mortality of URB's above McNary Dam is zero, while mortality of SRB's averages 12% to Ice Harbor Dam with additional mortality to Lower Granite Dam and to the spawning areas above;
- As a result of the above points, CWT's recovered in the Snake River are expanded twice that of URB mid-Columbia recoveries.

Bias #3. Incidental/latent mortality and illegal take are unaccounted losses due to harvest:

- Incidental mortality of unlanded catch (net injury & marine mammal predation);
- Latent disease and pre-spawning mortality caused by wounds and stress caused by capture and escape from fishing gear;
- Harvest-related wounding of fall chinook salmon at Ice Harbor Dam ranges 27-37% (Table 15; Mendel 1993);
- Illegal catch is not quantified as an explicit loss in river harvest accounting;
- High-grading or bias in selection of home pack (selecting adipose marked fish with CWT or visual identification of upriver stocks) could bias interpretation of landing recoveries;
- An inverse relation exists between in-river harvest levels and inter-dam conversion rate Figure 14).

Bias #4. Fixed Escapement Policy of 45,000 URB at McNary Dam:

- No management goal is established for spawning escapement SRB's;

- The 45,000 goal is not sensitive to the SRB/URB ratio which varies from 0.4 to 1.6%; For example if wild SRB's comprise 1.6% of aggregate URB run, then McNary passage is 720, but if wild SRB's comprise 0.4% then McNary passage is only 180;
- Given the 45,000 McNary escapement: target -- if URB run size increases and SRB run size is stable or decreases, then SRB harvest rate will increase;
- The 45,000 McNary Goal does not ensure spawning escapement of SRB's.

Bias 5. Critical uncertainties exist in data, functional cause-effect relations, and key modeling parameters:

- No harvest recovery data or Stock-Recruit relations exist for wild SRB's -- the surrogate stock is the Lyons Ferry Hatchery CWT releases;
- The Stock-Recruit function, based on mid-Columbia or LFH data is not reliable;
- SRB escapement is not corrected for fallback observed in radiotracking studies;
- Effect of spawning below SR dams (e.g., Umatilla strays) on recruitment is not known;
- Most harvest analyses used for management are deterministic, not incorporating stochastic variation;
- Ocean age-specific mortalities are gross estimates, not based on empirical data;
- Empirical data are non-existent to estimate brood year survival rates or the functional relation with environmental conditions, but PSC and CRiSP harvest model results are very sensitive to the "EV scalars".

RECOMMENDATIONS

1. In-river exploitation rate goals for fall chinook should be set for age 4 fish, rather than for the combination of age 3 through age 6 fish as was done in the 1993 Biological Assessment on fall fisheries. Age 4 is the first year that the complete cohort is large enough to be fully vulnerable to in-river fisheries, and it is the dominant age at which females mature.
2. At present (i.e., until selective harvest is initiated) URB harvest rates equal SRB harvest rates. Harvest rates estimated by stock accounting for URB chinook should be used as the standard for estimating in-river harvest impacts on Snake River fall chinook. This estimation method is based on the greatest volume of data and has the fewest sources of possible bias.
3. Incidental fishing mortality of unlanded catch, latent mortality of escaped fish that are stressed/wounded, and illegal harvest should be accounted for in assessing the total impacts of harvest on Snake River fall chinook salmon.

4. Stock accounting for SRB chinook should use Lower Monumental Dam rather than Ice Harbor Dam as the terminal point -- because it has been documented by radio tracking studies that fall back is much lower at Lower Monumental than at Ice Harbor.
5. Fallback (multiple ascensions and mortality) should be accounted for in estimating passage above Lower Granite Dam.
6. A spawning escapement goal should be established for naturally spawning Snake River fall chinook at Lower Granite Dam -- in addition to the brood stock management goal at Lyons Ferry Hatchery. The management goal of 45,000 at McNary Dam does not ensure adequate SRB escapement.
7. A valid SRB production function is needed to model harvest impacts on the Snake River stock. An adequate data base to accomplish this requires more subyearling CWT releases at LFH and tagging natural production if possible.
8. The feasibility of selective harvest of strong stocks of URB's, live capture and release of SRB's, and regulations to restrict harvest of large female chinook should be evaluated. If selective harvest could be implemented that was greater than 70% effective -- it could provide more harvest opportunity on URB's and reduce harvest impacts on SRB's.

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Appendix 1. Sex data on CWT's from Lyons Ferry Hatchery. Source: PSMFC database.

1984 Brood Lyons Ferry Stock (On-station only)

Age 2	Fish Sampled Males	Females	Totals
Ocean	7	3	10
River	9	0	9
Hatchery	0	0	0

Age 3	Fish Sampled Males	Females	Totals
Ocean	1	0	1
River	21	9	30
Hatchery	62	37	99

Age 4	Fish Sampled Males	Females	Totals
Ocean	0	0	0
River	15	43	58
Hatchery	26	32	58

Age 5	Fish Sampled Males	Females	Totals
Ocean	0	0	0
River	2	8	10
Hatchery	5	5	10

% Males

Males	Ocean	River	Hatchery
Age 2	70%	100%	0%
Age 3	100%	70%	63%
Age 4	0%	26%	45%
Age 5	0%	20%	50%

% Females

Females	Ocean	River	Hatchery
Age 2	30%	0%	0%
Age 3	0%	30%	37%
Age 4	0%	74%	55%
Age 5	0%	80%	50%

Escapement to Tucannon River Not Included
Youngs Bay Not Included

Appendix 1. Cont.

1985 Brood On & Off-Station

	Fish Sampled		
Age 2	Males	Females	Totals
Ocean	1	0	1
River	1	0	1
Hatchery	0	0	0

	Fish Sampled		
Aae 3	Males	Females	Totals
Ocean	3	1	4
River	8	3	11
Hatchery	16	2	18

	% Males		
Males	Ocean	River	Hatchery
Age 2	100%	100%	0%
Age 3	75%	73%	89%
Age 4	0%	39%	27%
Age 5	100%	40%	52%

	Fish Sampled		
Age 4	Males	Females	Totals
Ocean	0		0
River	18	28	46
Hatchery	18	48	66

	% Females		
Females	Ocean	River	Hatchery
Age 2	0%	0%	0%
Age 3	25%	27%	11%
Age 4	0%	61%	73%
Age 5	0%	60%	48%

	Fish Sampled		
Age 5	Males	Females	Totals
Ocean	1	0	1
River	10	15	25
Hatchery	17	16	33

John Day Pool Included
Escapement to Hanford Reach, Tucannon and Snake River Not Included

Appendix **1.**

1986 Brood On & Off-Station

Age 2	Fish Sampled Males	Females	Totals
Ocean	0	0	0
River	0	0	0
Hatchery	0	0	0

Age 3	Fish Sampled Males	Females	Totals
Ocean	2	2	4
River	23	13	36
Hatchery	71	43	114

Males	% Males Ocean	River	Hatcher-v
Age 2	0%	0%	0%
Age 3	50%	64%	62%
Age 4	0%	42%	32%
Age 5	0%	43%	36%

Age 4	Fish Sampled Males	Females	Totals
Ocean	0	6	6
River	49	69	118
Hatchery	50	105	155

Females	% Females Ocean	River	Hatchery
Age 2	0%	0%	0%
Age 3	50%	36%	38%
Age 4	0%	58%	68%
Age 5	0%	57%	64%

Age 5	Fish Sampled Males	Females	Totals
Ocean	0	0	0
River	9	12	21
Hatchery	18	32	50

John Day Pool Included
Escapement to Tucannon River, Snake River, Hanford Reach and Youngs Bay Not Included